DOCUMENT RESUME

ED 041 756 SE 009 212

AUTHOR	Nice, Karl; And Others
TITLE	Science for Iowa Schools, Grades 4-6.
INSTITUTION	Iowa State Dept. of Public Instruction, Des Moines.
PUB DATE	68
NOTE	136p.
AVAILABLE FROM	Publications Section, State Dept. of Public Instruction, Grimes State Office Building, Des Moines, Iowa 50319 ($1.00)
EDRS PRICE	EDRS Price MF-$0.75 HC-$6.90
DESCRIPTORS	*Curriculum, *Elementary School Science, *Science Activities, Scientific Concepts, *Teaching Guides
IDENTIFIERS	Iowa

ABSTRACT

This guide includes four units for use in each of grades 4 through 6. The fourth grade units are entitled Measurement Systems, Classification Systems, Bio-Control Systems, and Hydrologic Systems; the fifth grade units are Chemical Systems, Force Systems, Bio-Systems, and Astro-Systems; and the sixth grade units are Equilibrium Systems, Geo-Systems, Space-Time Systems, and Repeating Systems. Each unit is introduced by a statement of behavioral goals for the unit and an outline of unit development. Concepts are then stated and followed by descriptions of student activities for developing each concept. Suggestions are given for evaluating each unit. Materials needed at each grade level are listed. (EB)

ED041756

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SCIENCE FOR IOWA SCHOOLS

GRADES 4-6

STATE OF IOWA
DEPARTMENT OF
PUBLIC INSTRUCTION

1968

SE 009 212

Price $1.00 per copy. Order from the Publications Section, State Department of Public Instruction, Grimes State Office Building, Des Moines, Iowa 50319.

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FOREWORD

The elementary student has a natural curiosity to explore the naturama which surrounds him. Concerted efforts by curriculum workers must be made to enhance this natural curiosity in all areas of the curriculum, not just in science. Science does, however, accord itself very well to this plan. The main theme of *Science for Iowa Schools, 4-6* is to magnify and to unfold this mental acquisitiveness common to children of this age. It is hoped the teachers of Iowa will be able to implement this approach to science teaching in their individual classrooms.

PAUL F. JOHNSTON
State Superintendent of Public Instruction

COURSE OF STUDY RATIONALE

MORE HAS HAPPENED in elementary school science in the past five years than in any other curriculum area. The many experimental programs in elementary school science being conducted in specific content areas in all parts of the United States are a good indication of the interest, concern, and general agreement that something is needed. As the total elementary school curriculum has developed over the years, science has been the one area that has consistently been omitted or not emphasized. Therefore, much is needed in curriculum planning and research before science is on a developmental level with the rest of the curriculum.

This situation, together with the tremendous increase in our scientific knowledge and the realization that young children are capable of understanding science, has caused a great change in the philosophy and teaching of science in the elementary school. It is generally agreed that science at any level should no longer be taught as a collection of facts. The facts become obsolete almost before they can be used, but the ways in which the scientific knowledge was obtained—the processes—will be useful for a longer period of time because they do not change.

The science program presented here emphasizes the way the scientist works — *the process* — rather than the facts, or *the product.* This program has been planned to take an entirely new approach to developing a guide which will be most useful for elementary teachers. A content outline, as found in many guides, will not be found as such here. Content is implied and its use described as a part of specific learning activities rather than stated as unrelated facts. The lack of a content outline in this course of study does not imply that it is unimportant. Knowledge should be gained by experimenting, recording data, and interpreting data with the aid of reference materials and teacher guidance. This can be accomplished only if the student is *actively* involved in learning science. The memorization of facts is not recommended because the student develops a fund of knowledge by becoming involved in the processes of science rather than by mere memorization.

The basic skills of observation, measurement, classification, recording and interpreting data, and making inferences and predictions are emphasized in this program. This is the way the scientist works, and thus it is logical to take this same approach when teaching science. The ability to predict accurately depends on observations made, measured, recorded, and classified. The processes lead to inferences which may, in turn, lead to significant predictions. Prediction is a logical and natural pupil activity, but it should be appropriately developed so that the pupil recognizes it as something more than a simple haphazard guess.

The theme of this science course of study for grades four through six is on the various systems which exist. The pupil thus gains a broad perspective and background of science while studying only selected, specific aspects. The program becomes less segmented or fragmented because of this broader emphasis. For this reason it may include a different combination of topics from that usually found in a recommended course of study for these grades.

This handbook is meant to serve as an aid for schools developing a science program or for those who wish to update an already existing program. It is not meant to be the prescribed course of study, because the educational needs of each community will vary. The science program should be kept as flexible as possible at all levels to meet these various needs.

It is obvious that the elementary school science program must provide the foundation for developing understandings needed in junior and senior high school science. If the suggestions in this handbook are followed, the pupils entering junior high school should be ready for the more sophisticated science program they will encounter there as well as in senior high school. They should also be able to understand better what is happening in the world around them.

T. R. Porter

Chairman, Science Committee

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GRADE FOUR

MEASUREMENT SYSTEMS

THE SKILLS of observation and measurement are basic to all scientific activities. Observation is the means by which the pupil explores. It is fundamental as an initiating activity in science. Observations, as registered by the senses, are formulated into descriptions by the pupil. The more accurate the descriptions, the more meaningful and useful are the observations.

Measurement provides the tool for adding accuracy and standardization to pupil observations.

Instruments are often necessary tools which extend the pupil's power of observation and measurement. In this unit the skills of *observation* and *measurement* are stressed to provide a foundation for additional skills which will be emphasized in the following units.

Unit Goals

Upon completion of this unit the pupil should be able to:

1. Distinguish between qualitative (what kind) and quantitative (how much) observations.
2. Develop an understanding of the arbitrary nature of units of measure.
3. Understand the need for standardized units.
4. Develop a knowledge of the several standardized units of measure in use.

Unit Development

The pupils' observational capabilities may be explored by having him make observations of curious objects which are not wholly exposed, thereby promoting guessing or imagination. The purpose, which should be appropriately discussed by the teacher, involves the realization that observations must be accurate and dependent solely on the senses. Interpretation, at this stage, is not suitable without more information. Note that pupil curiosity leads to the making of observations and that a truth about nature depends upon the correct usage of the sensory faculties.

Measurement may now be introduced with the pupils making individual observations of objects which possess characteristics that lend themselves to qualitative observations. The observations will be limited to the qualities (color, shape, etc.) of the objects; however, some students might interject quantity in a relative fashion by using *heavy*, *short*, *large*, etc. in their descriptions. A discussion should logically be developed concerning the resultant observations in terms of the following topics:

1. What senses did the pupil use to make his observation?
2. Why did or did not the descriptions differ from pupil to pupil?
3. What might be added to the descriptions to effect more accuracy and agreement in the observations?

From this discussion the pupils should, hopefully, realize the need for measurement as a tool for adding quantity to their observations.

The questioning pupils should then wonder how they can measure these objects. The pupils will construct their own units of measure in terms of a length of string, the width of their hands, the length of their fingers, etc. Pupils may then be asked to measure the same objects used previously and to express their descriptions in terms of numbers and the units constructed.

Based on these quantitative observations, a discussion should develop, emphasizing how numbers and units make the descriptions more exact. Stress should be placed on the idea that measurement simply involves the comparison of one thing (the objects) with another thing (the measuring tool).

Again, hopefully, the pupils should realize that the units used are not standardized. As a result, there is still something fundamental to measurement which is necessary if their descriptions are to agree and be meaningful. A follow-up discussion should lead the pupils to the obvious conclusion that the same unit must be used by all. The pupils must decide on a unit which each will use in the next measurement. Upon completion of this section, the pupils should be aware of the advantages of using the same unit and how such use will improve their observation descriptions.

Once the pupils have reached this level, the next step is the introduction of the two major systems of measurement. This includes a familiarization with the metric as well as the English system of measurement. The purpose is not the memorization of English-metric system equivalents or the practice of conversion from one system to the other. The pupils should develop a mental picture of the relative units of each system (e.g., a meter is longer than a yard, or one inch is longer than one centimeter) as well as an ability to employ the units in their measurements.

The pupil should now expand his thoughts to the level where he realizes that the linear measure (which has been used to this point) is not sufficient for measurement of mass (weight), volume, time, etc. The need for different units to measure different properties should have evolved.

The use of instruments as an aid to the senses in observation might be interjected at this point. By working with various instruments, pupils may realize the need for extending the senses in the exploration of the world around them and the significance of instruments to scientific progress.

The progress of the unit development depends on the pupil's formulating a picture of and a need for the next successive step to establish more reliable observations and measurements. Measurement, as such, can become laborious, however. If the pupil can realize the importance of adding quantity to his observations of nature and if he can realize the significance of measurement as a tool to scientific discovery, the study will be more meaningful.

Activities which support the matter-energy interaction theme are included here. This underlying idea should be emphasized whenever possible. However, observation and measurement are the topics of primary concern.

CONCEPT: Measurement is a useful tool of the scientist and is necessary for good observations.

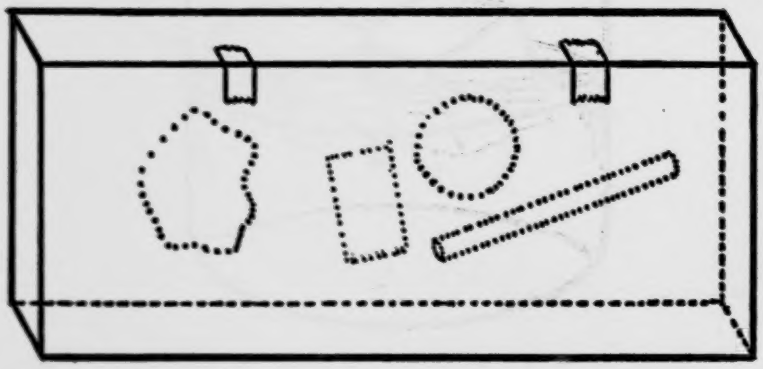
ACTIVITY 1. Testing Powers of Observation

Introduction

The purpose of this activity is to help the pupils test their powers of observation by using their senses. The pupils also are encouraged to guess and imagine so that they will realize the limitations of their observational abilities and understand the difference between an observation and an interpretation based on their observations.

Materials

Cigar boxes which have been taped or closed so that students cannot see inside.



Objects such as a cylindrical piece of wood, balloons filled with water, rocks, or substance with a peculiar smell placed inside the cigar box.

Procedure

Have pupils observe the boxes and describe what they see, feel, hear, smell, or taste without opening them. Let the pupils investigate the boxes as much as possible. After all observations have been completed, have the class make a comparison of the characteristics observed. List the characteristics on the board. Lead a discussion on why some of the observations are the same as others and why some differ. Have the pupils identify the senses used in making the observations. Then lead the discussion so that the pupils discover the difference between an observation and an interpretation of an observation.

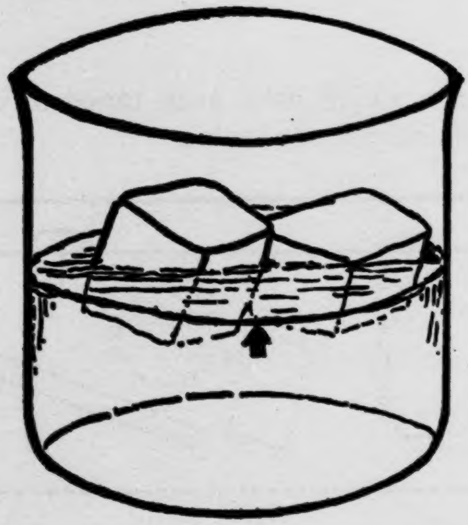
ACTIVITY 2. Why Don't Ice Cubes Raise the Water Level in a Glass As They Melt?

Introduction

The purpose is to cause pupils to guess the outcome of the activity first and then to show them the necessity of performing the activity and observing the results for their proof. The emphasis is on the need for making observations and making them accurate. Introduce the pupil to measurement in the quantity determination of the water level.

Materials

large beaker or glass
water (preferably lukewarm)
ice cubes
marking pencil



Procedure

First have pupils guess the effect on the height of the water level as the ice cubes melt. Then have them fill a container approximately half full of water. Place a couple of ice cubes in the water and carefully mark the level of the water in the container with a marking pencil. Observe the results as the ice cubes melt. Discuss the need for making observations and the need for making them accurate.

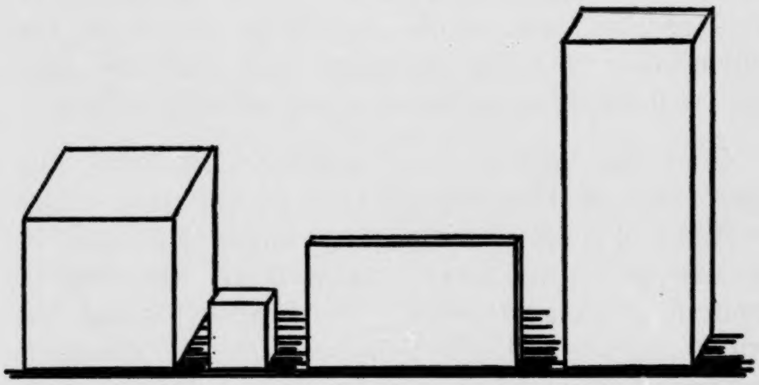
ACTIVITY 3. Qualitative Observations

Introduction

In this activity the pupils should become acquainted with observations based entirely on the qualities of the objects used. The properties of the objects should emphasize color, shape, hardness, etc. The purpose is to cause the pupils to develop a need for adding quantity as well as quality to their observations and therefore provide for more accurate and precise descriptions.

Materials

Objects which are basically the same in color, shape, hardness, texture, etc. Blocks of wood ranging from very minute to rather obvious size differences.



Procedure

Pupils should work individually or in groups of two if possible. Have them write out descriptions based on their observations. These observations will primarily be descriptions of the color, shape, and other qualities of the blocks. The pupils should note very little significant difference between the objects based on their qualitative observations. Most of the pupils will include relative quantities in their descriptions by stating large, small, heavy, short, or other similar terms. Thus, the need for adding quantity to their descriptions should develop.

Encourage the pupils to use relative quantitative terms in the follow-up discussion, but emphasize such things as "large or small compared to what." Obviously, the pupils will feel the need for a measuring device, but do not give them one. In the discussion of this activity, attempt to differentiate between qualitative and quantitative observations and the significance of measurement in further observations.

CONCEPT: Measuring is comparing with standard units of measurement.

ACTIVITY 1. Constructing Units of Measure

Introduction

The pupils now have a need for measurement as a tool in formulating their quantitative observations. Activity 1 involves the construction of units of measure to illustrate that those units are arbitrary things and serve as a means for comparing one object with another. The units serve as implements of quantity to aid their observations.

Materials

Wooden blocks of various sizes (same as used in Activity 3 of the previous concept). Table tops or any other easily measurable objects. Strings of equal length or wood rods of equal length.

Procedure

Using the devices (string, wood rods, etc.) have pupils individually or in groups of two measure the objects. The string or rods should be of appropriate size so that the objects can be measured without too many fractions of units. Allow the *pupils* to determine the lengths of their units by themselves. There will be varying lengths, and this should promote the idea of the arbitrary nature of measurement. (Note: Problems might develop when the measurements are in fractions of units.) Pupils should supplement their qualitative observations with their quantitative observations. The measurements will be expressed in terms of units of string, units of wood, etc. Discuss the results in terms of the following points:

a. Does quantity place any greater significance on the observations?

b. What are units of measure?

c. What procedure is followed in measuring (comparison of one object with another)?

d. Does measurement establish more precise or exact descriptions of the objects?

e. Why must the units be the same for all students to become meaningful?

ACTIVITY 2. Constructing a Standardized Unit of Measure

Introduction

The necessity of a standardized unit for measuring should become evident to the students after completing Activity 1. Activity 2 reinforces the need for standardization of measuring units and includes the development of a standardized unit. The activity allows for the measurement of area and volume in terms of the evolved unit. The use of the last section will depend on the progress of the class.

Materials

paper
ruler

Procedure

Ask the pupils to describe accurately the tops of their desks qualitatively. After the completion of Activity 1, they will wish to employ quantity in their observational descriptions. Because they have previously been introduced to standardized systems of measures, they will wish to describe their desk tops in terms of numbers and a standard unit (feet or inches). Point out that they made reference not only to numbers but to a unit which has been standardized.

Suggest that class members set up their own standard units of measure by using the widths of their hands. The hand unit is the width of the hand immediately below the base of the fingers. Have each pupil measure the width of his desk top in terms of this new unit. When each has made his measurement, record the measurements obtained on the chalkboard.

Assuming that the actual dimensions of the desk tops are the same, point out that some measurements are difficult from others. The follow-up discussion should lead to the conclusion that to be accurate they must decide upon just one pupil's hand as a standard. Select a pupil and mark the width of his hand on the chalkboard. Using this as the standard unit, have each pupil in the class bring a piece of paper and pencil to the board and mark the width on the edge of his paper.

Utilizing this new standard, have the pupils remeasure their desk tops. Do the results from this measurement agree? The discussion should stress the arbitrary nature of measurement units and the need for a standardized unit. If the measurements still are not equal, emphasize the need for accuracy. Have the pupils compare their pieces of paper and note any differences in the width of the marks that they have drawn. The error may be accounted for, in part, by the width of the chalk lines or an inaccuracy in transferring the width to the paper.

If the measurements come out in an uneven number of hand widths (e.g. 6½ hands), suggest that the hand may be subdivided into smaller units for more accurate measurement. Using the ruler, have the pupils divide the hand width into 10 equal parts. This will probably require much teacher assistance. Because of the arbitrary hand width, the 10 units might not correspond to centimeters or inches; therefore, the need for teacher help. The succeeding measurements will emphasize the importance of the subdivision of units and the need for accuracy in measurement.

If appropriate, the teacher may assign pupils the determination of the surface area of their desk tops in the hand units. This exercise points to the need for a new unit of area and can be expressed in square hands. Using this process, some pupils may be capable of determining the volume of the desk top (i.e. length x width x height).

ACTIVITY 3. Familiarization with Standard Systems of Measurement

In the preceding activities (Activities 1 and 2) the pupils have evolved units and developed a standard unit for use in the classroom. Obviously the pupils are aware of the existence of the standardized systems of measure.

The purpose of this activity is a basic review of the English system of measurement and an elementary familiarization with the metric system of measurement. Do not stress the English-metric unit equivalents or the conversion from one system to the other. The pupils, hopefully, will develop a working knowledge of the relationship between these two systems of measurement. Encourage the pupils to utilize the metric system in the remaining activities of this unit as well as in all succeeding units.

Procedure

a. Discuss what is meant by standardization of measurement. Remind the pupils that they have experience with standardized systems of their own making. Discuss properties of a standard unit: (1) has transportability, (2) usable for varying nature, (3) is exactly known, (4) possesses ease of reproducibility, etc.

b. Review the English system. Stress the property being measured and the unit that the English system uses to measure this property. A table such as the following may be helpful:

English Unit	Properties
foot	length
gallon	volume
pound	weight

c. Look at the metric system. Review its historical development. State that the metric system has the following units of measurement for these same properties. Present the following table:

English Unit	Properties	Metric Units
foot	length	meter
gallon	volume	liter
pound	weight	gram

Show an example of each of the above kinds of units to the class.

d. Ask the question: What is the difference between the metric system and the English system? Some possible answers pupils may suggest:

Metric system is more accurate.
Metric system is more scientific.
Metric units are better.
Metric units are different sizes.

Note that the first three of the above are not true and that the last is true. When this last suggestion has been made, ask: Does the difference in size make the metric system better than the English system? Lead the pupils to understand that some units will be of better size for measuring some things than others. Have the class compare the length of a meter with a yard, the volume of a quart with a liter, and a pound with a gram. Note that the first two are nearly the same in size while the last case shows considerable difference. Conclude that some of the units of the metric system are similar in size to the corresponding units in the English system and that therefore they could be used to measure the same properties of similar-sized objects.

e. Ask the question: Why then do we need a metric system of measurement? Leave this question unanswered until you have finished this activity. Provide the pupils with meter sticks, rulers, gallon containers, liter containers, spring balances which measure pounds, and others which measure grams. Direct the pupils to measure several objects around the classroom (or on the playground) and determine the volume of some containers. Ask them to repeat the measurements to be sure that they are correct. Have them measure these objects in the metric system as well as in the English system and carefully record these readings on the blackboard for the entire class to compare. Make verbal comparisons between the two systems for each property. Now ask the pupils to return to the activity and discuss the fundamental relationships.

Somewhere near the middle of this activity call all the pupils together and ask what they do when an object is so many feet plus a little more. They will probably answer measure the rest in inches. This is a good time to ask them to list the subdivisions in the English system for each property. That is, 1 gallon is 4 quarts, 8 pints, 16 cups, etc. Note that the foot is subdivided into inches and sometimes into fractions of an inch. Ask: In the English system how do we measure long distances such as the distance across the football field? Yards. In other words, we use multiples of units in the English system to get to the large units.

Now turn to the metric system. Ask pupils to look at the meter stick and see if they can discover how it is subdivided. Hopefully someone will suggest that the meter stick is subdivided into 10 divisions each of which is in turn subdivided into 10 divisions.

Ask how many divisions are marked on the meter stick — 1,000. State that each subdivision by 10 is a unit of measure in the metric system:

1/10th of a meter is one unit — decimeter.
1/10th of 1/10th is another unit — centimeter.
1/10th of 1/10th of 1/10th is another unit— millimeter.

It is convenient to relate the above to our monetary system:

A dime is 1/10th of a dollar.
A penny (cent) is 1/100th of a dollar.
A mill is 1/1000th of a dollar.

Also note that it would be logical to have 10 times the meter, 100 times a meter and 1,000 times a meter for larger linear measures. These are called the decometer, the hectometer, and kilometer respectively.

ACTIVITY 4. Measurement—an Indicator of Change

Measurement is an important tool for detecting small day to day changes. In this activity a standardized system of measurement (metric system) will be used to measure the change in the length of shadow produced by a pole. The change in the shadow length could not be discovered without a quantitative observation. This activity may supplement the need for using quantity in pupil observations.

Materials

a stationary pole (fence post, broom handle, etc.)
meter stick
chart for recording data

Procedure

Locate a sturdy, stationary pole on the school grounds. The pole must remain in a fixed position so that reliable measurements can be obtained. If the pole is not stationary, the daily measurements will be of little value.

On the first day of the activity the teacher should lead the entire class through the measurement and recording procedure. Measure the length of the shadow from the base of the pole to the outermost point of the shadow, as accurately as possible. A chart for recording the daily measurements should be in an accessible position in the classroom.

After the first day, individual pupils should be assigned the measurement and recording process on a daily basis. This activity might best be done during the noon hour or during a recess period. However, it should be emphasized that the measurements must be taken at the same time every day of the school week. This factor is of extreme importance.

Continue the measurements for approximately four weeks or until there is some significant change in the length of the shadow. At weekly intervals (determine an appropriate interval to fit the data collected), discuss any changes that might have occurred and stress the significance of making the quantitative observation. Could the pupils detect the change without the measurements? It is important that pupils be reminded that the measurements must be very accurate. The day to day change might be so small that the measurements would have to be accurate to be meaningful.

In the discussions that should evolve from this activity, examine the reasons for the changes in the measurement. What other changes occur in nature that can be detected only by a quantitative observation?

Upon completion of this activity, the pupils should realize the significance of recording their daily observations in an orderly manner. They should also understand that their resultant conclusions are based on accumulated data which might or might not be accurate. Sound conclusions must be based on accurate observations.

CONCEPT: Different units are developed to measure different properties.

ACTIVITY 1. Measuring the Volume of the Lungs

This activity is designed to introduce the use of units of volume. The space occupied by a liquid and a gas will be measured in terms of the colu-metric unit. The pupils should not only become familiar with units of volume but also concentrate on accuracy in their measurements.

Materials

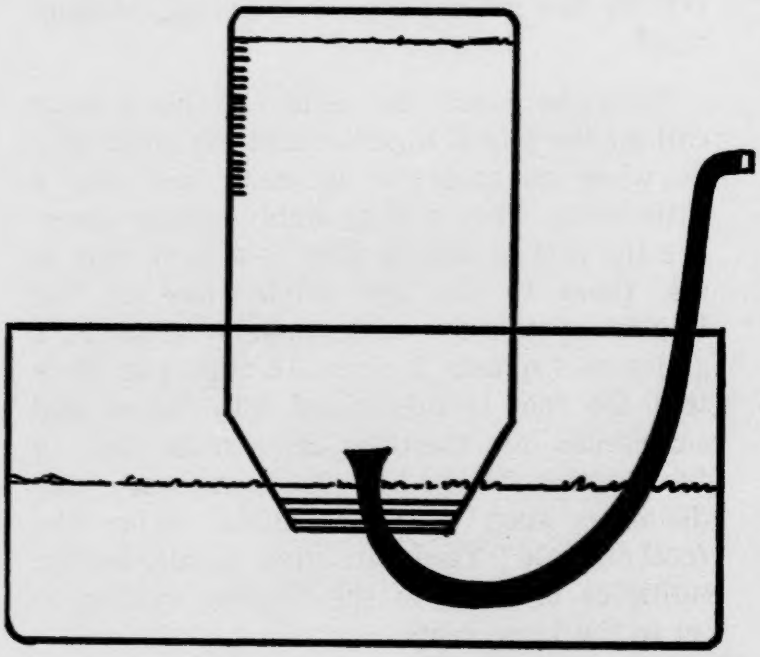
quart or half gallon milk cartons
graduate cylinders (100 or 1,000 milliliter)
pint measure
quart measure
gallon glass jug
rubber or plastic tubing (2-3 feet)
pail or plastic "sink"
marking pencil

Procedure

For this first part of the activity, have the pupils bring in the quart or half-gallon milk cartons. Cut off the upper "lid" section of the cartons so that only the body of the carton remains. Pupils will determine the volume of these containers by comparison with the quart and pint standard measures. By measuring the correct amount of water necessary to fill the cartons, the pupils should develop a knowledge of the English system units of liquid volume.

Next have the pupils fill the milk cartons with water, using the graduated cylinder. Determine the volume of milk cartons in the volumetric unit of the metric system. Milliliters or liters (1,000 milliliters = one liter) are the units the pupils should be associating with volume.

The teacher or any capable pupil may wish to calculate the volume of the cartons in terms of linear measurements. Calculate the volume in cubic inches as well as cubic centimeters. Note that one cubic centimeter is equivalent to one milliliter.



The second part of this activity establishes the relationship between volume and the space occupied by a gas. There is also a familiarization with the volumetric units employed.

Calibrate the gallon container (jug) by filling it with the pint or quart liquid measures and mark the resultant water levels on the outside with the marking pencil. Label the levels in the pint and quart units. Follow the same procedure using the metric unit measure (graduated cylinders), and mark 100 milliliter intervals for greater accuracy. The levels may be marked on opposite sides of the jug.

Completely fill the jug with water. Screw the lid on the jug and invert. Place the inverted jug in the pail or plastic "sink" which is 1/4 or 1/2 full of water. With the jug below water level, remove the lid. The jug should remain full of water for accurate results.

Carefully insert the tubing under the jug so that one end is under the container and the other end is hanging free outside the apparatus. Have a pupil take a deep breath and exhale into the tubing. The exhaled gas should replace the water in the jug. Carefully measure the volume of gas that has replaced the water. This reading is only an approximate determination of the lung capacity but serves as another approach to the determination of volume measurements.

The teacher might discuss what gases have replaced the water. Emphasize the units of volume utilized and mention that gases can be measured in volume units. Have other pupils follow the same procedure for comparative purposes. To create interest, record the results on the chalkboard and discuss.

Discuss the significance and application of volume measurements in quantitative observations.

ACTIVITY 2. Weight Measurements

The purpose of this activity is two-fold. First the pupils will review the arbitrary nature of measurement units by establishing their own units of weight. (There is no attempt to differentiate between weight and mass at this point, unless the teacher so wishes.) The pupils will then investigate the standard units for measuring weight to further their understanding that different units are developed to measure different properties.

Materials

balance

objects such as paper cups, wooden blocks, chalk, pencils, etc. (Some of the objects should be approximately the same weight.)

box of paper clips or some other small, uniform objects

set of gram weights

Procedure

Initiate this activity by having pupils determine the relative weights of the wooden blocks, pencils, chalk, etc. This can be accomplished by having the pupils lift each object to determine how heavy it feels when lifted as compared with one of the other objects. Discuss the inaccuracy and relative nature of this method.

Next use the balance as an instrument for comparing the weight of the same objects with an arbitrary unit of weight—paper clips. Discuss the balance as an instrument which tells how much something weighs compared to something else.

By balancing the objects with the paper clips the pupils are comparing with their own unit of measure—a paper clip. The pupils will then express the weight of the pencil, for example, as 50 paper clips. This provides an opportunity to again discuss the arbitrary nature of units of measurement. Have the pupils weigh some objects used in the lifting exercise to determine the accuracy of the lifting method.

Since paper clips are obviously not standardized units of measurement, introduce the set of gram weights as the standard unit of weight in the metric system. Have the pupils weigh the same objects used previously with the gram weights. If there are English unit weights available, use them for comparing the weight units of the two measurement systems.

Discuss the gram in terms of a standardized unit of weight. Discuss the importance and application of weight measurements in quantitative observations.

ACTIVITY 3. Measuring Temperature

Temperature is considered a fundamental property in science. The purpose of Activity 3 is the introduction of degrees as the unit of temperature measurement. The pupil will also become familiar with the Fahrenheit and Celsius (centigrade) standard scales and thermometers.

Materials

thermometers
  Fahrenheit (0 degrees to 215 degrees)
  Celsius (-20 degrees to 110 degrees)
beakers
heat source
ice cubes

Procedure

Prepare three beakers of water of varying temperatures. The temperature differences should be subtle, yet detectable by the sense of feel. (Caution: Warm water should not cause any discomfort when fingers are submerged in the water.)

Choose one pupil to determine the relative temperature of each beaker of water and describe in terms of one being hot or cold compared to the others. Select another pupil to follow the same procedure. Are the observations the same? How reliable is man's sense of touch? Discuss the observations in terms of how hot or cold each beaker is compared to what?

Have the pupils suggest a more accurate method of determining the temperature of the water so that each pupil knows exactly how the temperature of one beaker compares with the other. Since the thermometer will be the instrument chosen by the pupils, inquire into the standard units used in measuring temperature. Show the class two regular laboratory or wall-type thermometers, one with a Celsius scale and one with a Fahrenheit scale. Explain to the pupils that these thermometers are both used to measure temperature but possess different standard scales. Point out to the pupils that these scales are similar to the standard inch and centimeter scales used in measuring length.

This second stage of the activity will serve as an introduction to: (1) the use of thermometers as a measure of a different property, (2) Fahrenheit and Celsius temperature scales, and (3) freezing and boiling point temperatures and normal room temperatures. Have the pupils work in groups of four or five if sufficient thermometers are available. The boiling point temperature determination should be done by the teacher for safety reasons.

Using one Fahrenheit and one Celsius thermometer per group, the pupils will determine room temperature and ice and water mixture temperature by reading the temperature scale on each thermometer. The teacher, with aid from the pupils, may find the boiling point temperature using both thermometers. The pupils may need help in reading the scales. Write the results on the chalkboard, listing both sets of temperature readings.

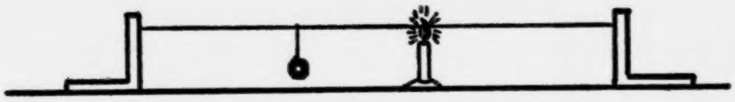
Discuss the results and emphasize the importance of temperature measurements in the making of observations. What applications might pupils have for making observations involving temperature?

ACTIVITY 4. Measurement of Change

The emphasis in this activity involves the basic theme—the interaction of matter and energy, producing change. Measurement is presented as a tool of the scientist for formulating accurate descriptions of his observations so that other scientists will have a true picture of what he is describing.

Materials

two wooden supports
copper, aluminum, and iron wire
weight (heavy bolt or steel nut)
heat source



Procedure

String the copper wire between the two supports so the wire is about 15 inches above the table top. Suspend the weight by a string or wire from the center of the wire. Be sure to have a standard distance between the top of the table and the base of the weight before heating. Heat the wire by moving the heat source along the wire. Observe. What is interacting (matter-wire; flame-energy)? Describe the results.

Would it help to know how much the wire moved and to include this measurement in the observations? How would measurement improve your observation? How much did the wire move for a given period of heating? (Vary the heating period and measure results.) Record the measurements on the chalkboard.

Use the other two types of wire and follow the same procedure. Use similar time intervals for heating so results may be compared. In which wire was the greater change for a given period of heating? Is measurement necessary to determine the changes in each wire?

The discussion should logically include the value of measurement in accurately describing changes. What units of measure would be used in measuring the change?

CONCEPT: Instruments extend the senses for making observations and measurements.

ACTIVITY 1. Demonstration of Some Scientific Instruments

Scientific instruments are used to make observations and to measure properties which the unaided sensory faculties of the human being are incapable of doing. This activity introduces to the pupil only a few of the scientific instruments and should illustrate how some instruments extend man's power of observation and aid in compiling quantitative observations.

Materials

- magnetic compass
- light meter
- telescope
- microscope
- prepared slides or pond water

Procedure

Depending on their availability, any or all of the instruments may be used in this demonstration. (The teacher may substitute other appropriate instruments.)

The compass can simply be demonstrated as a tool for detecting the magnetic field of the earth. Ask the pupils if they can feel or detect the magnetic field without the use of this instrument. How does this instrument extend man's powers of observation? How could this force be measured?

Using the light meter, measure the intensity of light in the classroom. There is no need for explanation of the units involved or an explanation of the operation of the light meter unless the teacher wishes to do so. Discuss the terminology (bright, dim, etc.) which pupils should use in their descriptions of the light. Initiate suggestions from the pupils as to why the light meter is more accurate and is a useful tool to the scientist. How does this instrument aid the senses?

If a telescope is available, have pupils make individual observations, using this instrument. What new fields of exploration were opened to the scientist with the invention of this instrument? How does it aid the sense of sight in making observations?

Introduce the microscope as another scientific instrument which opens a new field of observation to the scientist. Have pupils observe prepared slides, pond water, etc. Discuss how their powers of observation have been improved. What can they see with the aid of the microscope?

EVALUATION:

The unit evaluation should not emphasize factual recall of the fundamentals of observation and measurement. Stress understanding of the concepts and implementation of the concepts. This might best be accomplished through a laboratory practical examination.

Can the pupils make accurate observations? An activity requiring the making of quantitative observations will test their ability to involve measurement in their observations.

Have pupils construct their own units of measure, using linear, volumetric, or weight units of measurement. Are the pupils able to measure accurately using these arbitrary units?

Evaluate the pupils' ability to measure volume, weight, or temperature, using both the English and metric systems of measurement. Select appropriate objects which will lend themselves to these measurements. Do not demand recall of English and metric units or equivalents and conversions between the two systems. Use this opportunity to test the pupils' ability to measure, using the two standardized systems of measure.

Evaluate the pupils' understanding of instruments as a tool of the scientist. Allow the pupils to use an instrument which extends their senses and ask them to explain their increased powers of observation in terms of aiding man's observational capabilities.

CLASSIFICATION SYSTEMS

AS THE SCIENTIST observes and measures, he is impressed by the number of facts before him. He is immediately faced with remembering and synthesizing these observations into meaningful relationships. Classification provides a tool for the organization of the observations and a source for generalization and prediction about the relationships which exist in nature.

Unit Goals

Upon completion of this unit the pupil should:

1. Understand the values and limitations of classification in the scientific process.
2. Be able to devise a scheme of a classification.
3. Know some classification schemes that scientists use.
4. Develop an understanding of sets and subsets.
5. Understand that classification is a common experience in science and daily living.

Unit Development

To an adult who has used classification schemes all his life, the concepts in this unit must certainly seem elementary. Remember, however, that our purpose is not just to introduce new material. Rather it is to begin with those aspects about classification with which the pupil is most familiar and proceed to those which are less familiar.

The concept involves a word which fourth graders may not have used in just this way. That word is *property*. The properties of an object enable us to distinguish it from other objects. Perhaps a discussion about the distinguishing *properties* of the members of the class would be valuable here.

The initial activity for the first concept uses a common object which should appear to the pupil to be completely divorced from science. This is intended to be the case. Just the process of classification is to be emphasized here.

The second and third activities are closely related to the first. The latter is to be terminated with the idea of set as it applies to the buttons. The pupils may already have had this terminology in their math. If not, the teacher should illustrate the concept of set by taking a set of buttons and subdividing them into subsets and discussing their interrelationships.

Activities 4 and 5 emphasize that classification procedures are common everyday experiences and will help the pupil to develop further the concept of set and subset.

Activity 6 will be used to relate the classification system to nature. Let the pupils develop their own words for describing the properties of a leaf. Differentiating names for these properties will be used later in the unit. The purpose at this stage is to have the pupils recognize that leaves have different properties. The teacher may wish to save the tree leaves for use later in this unit. This last activity should lead naturally to the next concept.

The second concept deals with classification as the means by which man organizes the diversity of nature. The first task is to convince the pupil that nature is indeed diverse. The first activity seeks to do this and at the same time attempts to convince the pupil that there are different bases for establishing categories. In the second activity two things should be accomplished. Pupils have been starting with objects and setting up their own categories.

Now they should grasp the idea that it is possible to start with already established categories and fit the objects to them. Also, the pupils should begin to understand the established systems that scientists use. The next concept will develop this further in establishment of the plant-animal relationship and in the metal-nonmetal classification.

In the final concept we deal with the man-made nature of classification systems. The emphasis here should be that the classification of plants or animals or elements does not necessarily represent the interrelationships which exist in nature but is really man's attempt to organize nature so that these relationships may be discovered. If this is true, then it follows that classification does not represent nature perfectly. Hence, nature will not fit man's classification scheme perfectly.

Begin this first activity with discussion of the plant vs. animal concept. The idea is to provide a plant which does not fit into the scheme developed for classification. If one can get the small organism, *Euglena,* and have access to microscopes or a microprojector, a green organism can be shown which is mobile and therefore does not fit the animal scheme very well. Activities 2 and 3 are meant to expose the pupil to another classification problem and at the same time give the pupil some experience with the chemical elements. The teacher may need to get the help of a local junior high or high school science teacher to find some of these materials. Actually, all could normally be found at home, in a hardware store, or a drugstore, but help might be needed to identify them.

CONCEPT: Classification provides a means by which man organizes the diversity of nature.

ACTIVITY 1. Classifying Plants

Introduction

This activity is different from the third activity in the previous concept in that the emphasis will be on different ways to classify. Again we will deal with subjects somewhat familiar to the pupils.

Materials

None

Procedure

Have the pupils name as many different plants as they can and compile a list for the entire class. This list should be so long that the pupils should be impressed by large numbers. Ask how these might be classified. Some will be flowers, vegetables, shrubs, crops, trees, etc. Explain that these are largely categories according to use. Ask if there is some other basis on which they might classify this list. One would certainly be the ways the plants are related to each other. Other ways would be where they grow, whether they are annuals or perennials, and size.

ACTIVITY 2. A Key

Introduction

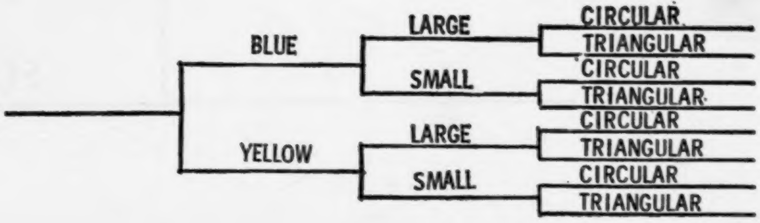
Up to now the approach has been to take the objects and observe their properties and decide on an appropriate classification system of the pupils' own choosing. A very common way of classifying objects in science is to start with the classification system and fit the objects into it. An established system of classification is called a key. A key can be used to put the object in its proper relationship to other objects.

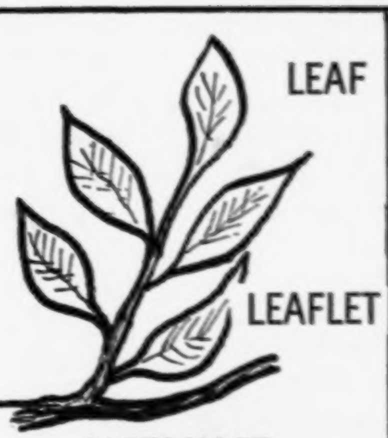
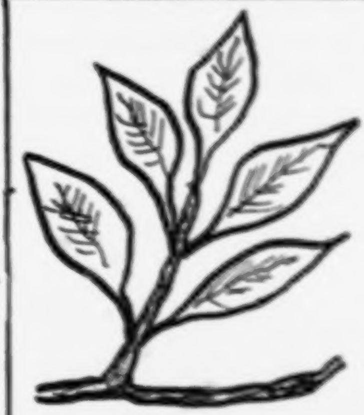
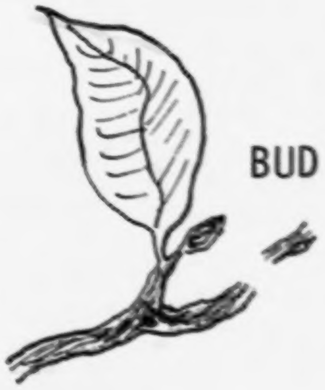
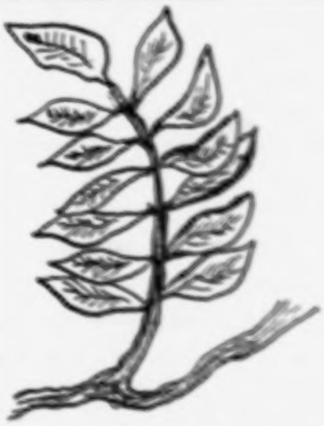
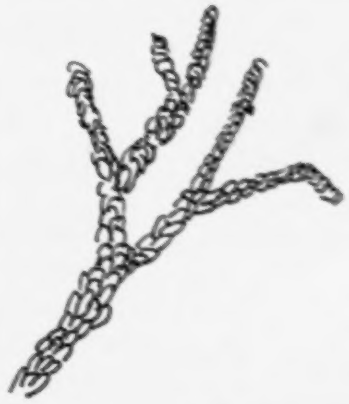
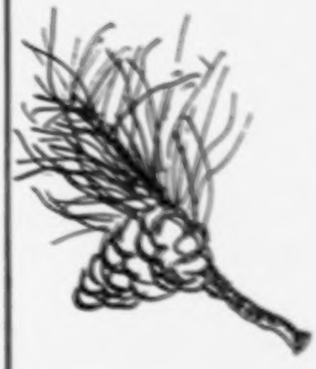
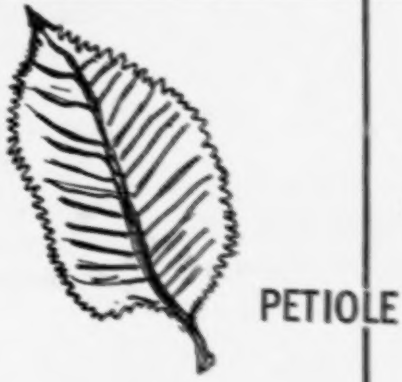
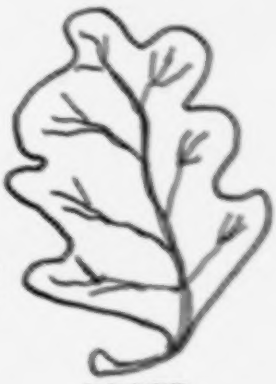
Materials

Two colors of construction paper

Procedure

Cut two different shapes of objects out of two different colors of paper. Also cut two different sizes of these different shapes. For example, cut a large and a small triangle from each color, then cut a large and a small circle from each color. Provide enough so that each pupil will have a complete set for each. Ask the pupils to organize some kind of classification scheme. Stress that one can correctly make the first subdivisions on the basis of color, size, or shape. After the pupils have had an opportunity to do this, call them together and place the following flow chart before the class. Tell the pupils that this chart could be used in the future to classify this set of objects. It would in that case be called a key.



LEAFLET ARRANGEMENT	 LEAF LEAFLET ALTERNATE	 OPPOSITE
LEAF COMPLEXITY	 SIMPLE	 COMPOUND
LEAF SHAPE	 AWL SHAPE	 NEEDLE
LEAF EDGE	 SERRATED	 LOBED

Ask the pupils what the first basis for division was. Then ask for the second basis, and the last basis. Ask how the chart would be different if there had been another color. How many more positions would be needed? Ask the pupils to suppose that it was later found that there were two different kinds of yellow paper used. How would the chart have to be rearranged? The teacher will wish to redraw the yellow leg of the chart to subdivide it for the different kinds of paper. This might be done at any point.

The pupils should be told that the properties of the above objects are easily described in one word but that this is not often the case in nature. Generally a short description of the property is needed; hence it is not possible to draw the above flow chart because of the length of the description or number of properties.

Place the chart with numbers before the pupils again. Give each pupil a piece of paper and ask him to write down each step as he classifies it. When they have finished, do a sample quickly. Your results should look like this:

First: choose blue or yellow.
Second: if blue, proceed to large or small.
Third: if small, proceed to triangular or circular.
Now go back and put in the numbers.
Begin at 1; if blue, go to (2); if yellow, go to (7).
If blue and large, go to (3); if blue and small, go to (4).
If yellow, go to (9).
If large, go to (10); if small, go to (11).

Now the pupils should be ready to construct a key in list form, using the flow chart to tell which branch to take after each property. The next step will be indicated by a number in parenthesis. Lead them to develop the following key in list form:

1. a. blue (2)
   b. yellow (5)
2. a. large (3)
   b. small (4)
3. a. circular
   b. triangular
4. a. circular
   b. triangular
5. a. large (5)
   b. small (6)
6. a. circular
   b. triangular
7. a. circular
   b. triangular

Have the pupils practice using this list key a few times.

At this point the pupil can be led to classify leaves according to a tree key. If leaves from the previous experiment have not been saved, a field trip to nearby trees will produce a collection of leaves. The teacher may wish to restrict the area from which the leaves are collected to facilitate classification according to the table similar to the following. Since all these kinds of trees may not be in the area and others may be, the teacher will need to modify the key to fit the trees to be identified. It is important to keep the key simple.

KEY

1. a.	Leaves, evergreen, awl-shaped or needle-like (2)	
b.	Leaves that fall in autumn (5)	
2. a.	Needle-shaped 2 to 5 in a bundle	pine
b.	Leaves not in bundle (3)	
3. a.	Leaves awl-shaped or scale-shaped	cedar
b.	Leaves not awl-shaped (4)	
4. a.	Leaves four-sided, scattered on all sides of twig, stiff, short	spruce
b.	Leaves blunt at outer end, flat, short	hemlock
5. a.	Leaves simple leaf (6)	
b.	Leaves compound leaf	locust
6. a.	Leaves arranged opposite on twig	maple
b.	Leaves arranged alternately on twig (7)	
7. a.	Leaves pinnate and notched or lobed	oak
b.	Leaves not lobed, serrated edge, leaf base not symmetrical	elm

ACTIVITY 3. Classifying Matter

Introduction

This activity will consider a system undergoing a change in state. It will serve as a vehicle to the three goals. Those goals are: (1) to lead the pupil to discover that matter can be classified into one of three states, (2) to help the pupil define operationally the three states of matter, and (3) to mention briefly the conversion of one state to the other.

Materials

2-400 to 1,000 ml. pyrex beakers
ice
1 ring stand or tripod
1 burner or hot plate

colored water
baking soda
vinegar
different-shaped glass containers
candle
large glass tumbler
battery jar
wood splints
2 wide-mouth jars with lids

Procedure

Tell the pupils that they are to develop a description of the states of matter. Divide the class into four or five groups. Give each group a tray or a flat pan, a piece of chalk, some water in a beaker, and a glass. Tell the pupils that the glass is full of air. Instruct them to prepare a data sheet of three columns headed *Liquid, Solid,* and *Gas.*

Ask them to drop the chalk into the pan, pour the water into the pan, and then pour the glass of gas into the pan. Ask them to record their data in the table.

Some pupils may suggest that the gas cannot actually be seen here. If they do not suggest this, lead them to this point. Give them each a straw and instruct them to blow on the surface of the water and on the chalk and record their data. Some may say that the glass contained nothing. Carefully push an inverted glass down into a large glass battery jar. Let the class see that the water does not fill the glass; hence, it has something in it. Another way of "seeing" the gas is to place a short candle in a beaker and pour in carbon dioxide gas to extinguish the flame. This gas can be produced by mixing a few tablespoons of water with about ½ cup of vinegar. Do this as a demonstration for the pupils.

Assemble the pupils and discuss the data they have collected. Lead them to describe the states in such a way that they would be distinguished from each other. The first part of the activity will lead them to the concept of shape. At this point the teacher may wish to pour colored water from one container to the other, using different shapes of containers and perhaps inverting these containers and pushing them down into a battery jar. From this the pupils should conclude that solids have a definite shape, but that liquids and gases take the shape of their containers.

Ask how carrying gases, liquids, and solids from one place to the next is different. The pupils should suggest that a container is needed for gases and liquids but not for solids. Referring to the inverted containers of air in water, the pupil can be led to see that a gas fills its container. To demonstrate that gases need to have covered containers, generate two wide-mouth jars of CO_2 as described previously, put the lid on one, and leave the other open for the night. The next day, thrust a burning splint into each. The flame should go out in the capped jar.

Finally divide the class into four or five groups with the following set of materials:

a burner or a hot plate
a pyrex beaker
ice

Have the pupils place the ice in the beaker, then heat it gently until the ice melts. Then heat it more vigorously until it boils. Instruct them to hold a cool, dry glass in the escaping vapors.

Lead them to see that the water is a common example of the change from one state to the other. Ask what happened when the cool surface was held in the vapors. The pupils should conclude that the water changed back to a liquid. Ask:

Does this happen in other substances?
Does iron melt?
Does iron boil?

ACTIVITY 4. Energy Change and Changes in State

Introduction

An attempt has been made in this unit to develop the skills of observation and classification. Emphasis is placed on matter. In this activity the focal point will be on energy. Few concepts in science have been handled so poorly in the traditional outline as has been the concept of energy. On the one hand some have ignored it entirely, and on the other hand it has been relegated to a definition in terms of work. This activity will attempt to associate energy with changes in matter. The teacher should emphasize that when there is some change in matter, energy is always involved. The word *energy* should not be used until the conclusion of this unit.

Materials

1-100 ml. pyrex beaker
thermometer (centigrade)
ammonium chloride (NH_4C1)
burner
6-volt lantern cell

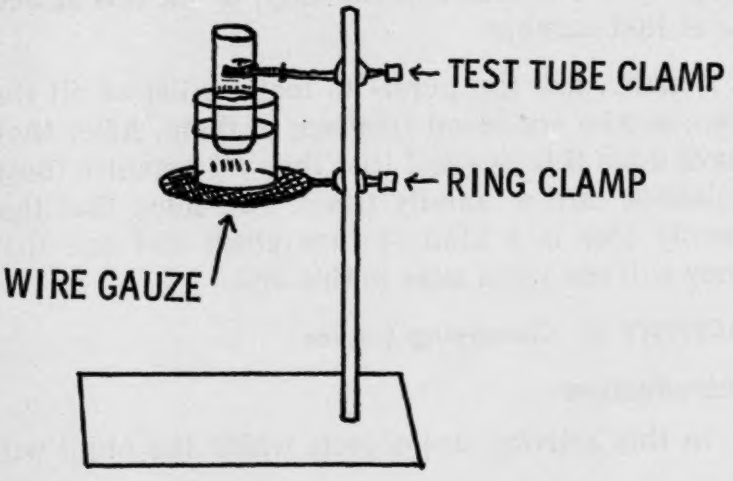
6-volt bulb and socket
ring stand and ring
test tube clamp
distilled water
modeling clay (two sticks for each pupil)
proof paper, photo copy paper,
or blueprint paper

Procedure

Divide the class into four or five groups and direct each group to get ½ beaker of water and record its temperature. This should be near room temperature. Give each group about a tablespoon of ammonium chloride. Direct them to add ammonium chloride to water and stir the mixture gently, watching the temperature as they stir. Ask the pupils to record observations. Set these mixtures aside for use later. Discuss the disappearance of the white solid and the drop in temperature. Emphasize these two things. The pupils will wish to say that the mixture became cold. Stress the fact that another way of saying the same thing is to say that it lost heat.

Provide each group with medium-size pyrex test tube, burner, thermometer, and enough paraffin to provide one to two inches in the bottom of the test tube. Direct the pupils to clamp the test tube to a ring stand with a test tube clamp and gently heat the tube until the wax melts. Ask the pupils to describe what they observe, stressing the aspects of what they say. CAUTION: Do not allow the pupils to overheat the test tube.

Have the class set up a 100 ml. beaker about half full of water. Record the temperature of the water. Check the wax to see if it is still melted. If not, direct the pupils to heat it until just melted. With the test tube in a vertical position, place the beaker of water on a ring attached to the stand and raise up under the test tube until the test tube with its content of wax is under the surface of the water, as indicated in the sketch. When the temperature change has stopped, ask the class to record the changes they observed. Do not let them forget that as the water was heated, the wax cooled and solidified.

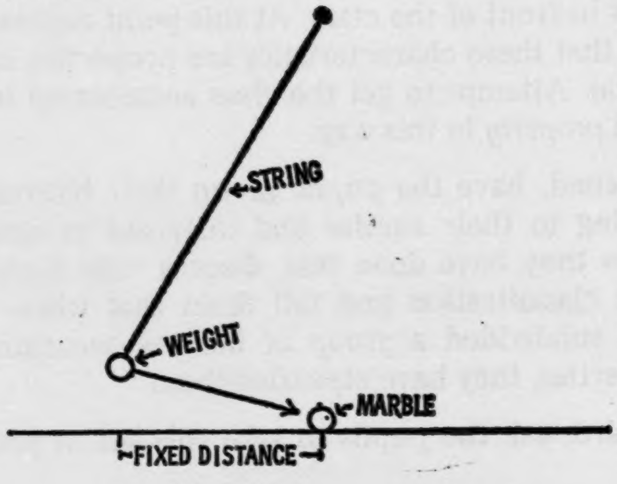


Give each group a piece of unexposed print-out or proof paper. Instruct the groups to quickly place a coin or a geometrical shape cut from construction paper on it. Have them place it in the window or put in a brightly-lighted area for several minutes. The photo paper will darken in a short time. Direct them to record their observations. Ask them what the change was. They will note the color. Ask them what changed the color of the paper. They will suggest the light.

Show the pupils a 6-volt battery, wires, and 6-volt bulb and socket. Ask them to describe what they see. Direct one of them to attach the wires to the battery and the bulb in such a way as to make the light burn. Ask what changes occur.

Return to the beaker of ammonium chloride and direct the pupils to place the mixture on a ring stand and heat the solution. If after standing, all of the solid has dissolved, add more so that a small amount is on the bottom of the beaker when they start heating it. They should heat it until they can see that more of the solid has dissolved. Ask them to record their observations. Discuss with the class the heat that was added and the change that took place in the mixture.

Place a metal weight on a long string suspended from as high as possible so that it just clears the floor. The ceiling will be best. Place a marble on the floor and see if the youngsters can hit the marble with the swinging weight by pulling the weight back a fixed distance. Ask them to compare the distance the weight swings when it hits the marble and when it does not hit the marble. See the sketch below.



Ask the pupils if they can see any change. They should eventually be led to conclude that the moving weight, when it hits the marble, causes the marble to move.

Now lead the pupils in a discussion of the six parts of this activity. Stress the fact that matter changed in each case. Ask what else happened. They should mention the heating, electricity, motion change, light, etc. Stress that these things have one thing in common; they are either forms of energy or they possess forms of energy. Caution the pupils to look for these and other forms of energy whenever matter changes.

CONCEPT: Classification schemes are based on the properties of the objects being classified.

ACTIVITY 1. Buttons for Classification

Introduction

In this first unit buttons have been selected for development of the concept of properties as the basis for classification. Buttons will appear unrelated to science from the pupil's point of view; hence, the pupils will not be distracted by terminology but will be able to concentrate on the process of classification.

Materials

Ten buttons per pupil (a good variety can be achieved by asking each pupil to bring 10 different buttons for use in this activity).

Procedure

First, ask the pupils to describe a group of buttons so that they have distinguished between the buttons. After they have written these descriptions down, compile a list of the distinguishing characteristics in front of the class. At this point express the idea that these characteristics are properties of the button. Attempt to get the class accustomed to the word *property* in this way.

Second, have the pupils group their buttons according to their similar and different properties. When they have done this, discuss with them the word classification and tell them that when they have subdivided a group of buttons according to properties, they have classified them.

Third, ask the pupils to take this list of properties and formulate classification schemes which will enable them to classify every button. When they have devised a scheme, give them new sets of 10 buttons and ask them to classify the sets, modifying their classification schemes as necessary.

ACTIVITY 2. Addresses are Classification Schemes

Introduction

In this activity the pupil will be led to see classification as a common everyday experience, one that is necessary for the efficient operation of society.

Materials

3" x 5" cards

Procedure

Give each pupil a 3" x 5" card and ask him to address it to his favorite out-of-town relative. Ask the pupils how they can be sure that the card will get to the person to whom it is addressed rather than to some other person. Lead them to conclude that each person has a unique set of properties in terms of his address, and that these properties are written down according to some system with which the post office department is familiar.

Next, give the pupils a list of 15 or 20 people who live in the same state. Use three or four different cities and three or four different streets in each city. Use the same house number for two or more. Be sure that the names are arranged at random so that the relationships are not apparent. Direct the pupils to group these people according to the things they have in common in their addresses. Lead them to recognize that all addresses have some things in common but that they also have some different properties. Point out that all members that have a property in common are members of the same set, i.e. they live in the set of people which live in this city, or on this street, or at that number.

Finally, ask the pupils to make a list of all the people who are blood relatives to them. After they have done this, suggest that they all organize these relatives into a "family tree." Tell them that this family tree is a kind of flow chart and one that they will see again later in this unit.

ACTIVITY 3. Classifying Leaves

Introduction

In this activity, use objects which the pupil will see as more closely related to science. Have the pupils bring leaves from home. A field trip to collect them would be better if possible or practical. Emphasize that as many different kinds of leaves as possible should be collected. Keep the leaves from drying by storing in the refrigerator in plastic or by wrapping each leaf in a plastic film. Fasten an identifying number to each leaf.

Materials

Leaf collection above

Procedure

Using the number of the leaf to identify it, ask the pupils to compile a list of the properties of a few leaves. Then make a list from the data of all the class. Ask the pupils to develop a classification scheme based on these properties. Finally, ask them to classify six or eight of the leaves in a flow chart diagram similar to their family trees. You may want to keep some of these around for use later in the unit.

ACTIVITY 4. Coding Systems

Introduction

Many classification systems are set up to code objects. A common example of this is the library where the books are coded according to their subject matter. The coding is done to the degree that every book fits the scheme somewhere. In this activity we will code the pupils in the room according to their interests: hobbies, pets, games they play, etc.

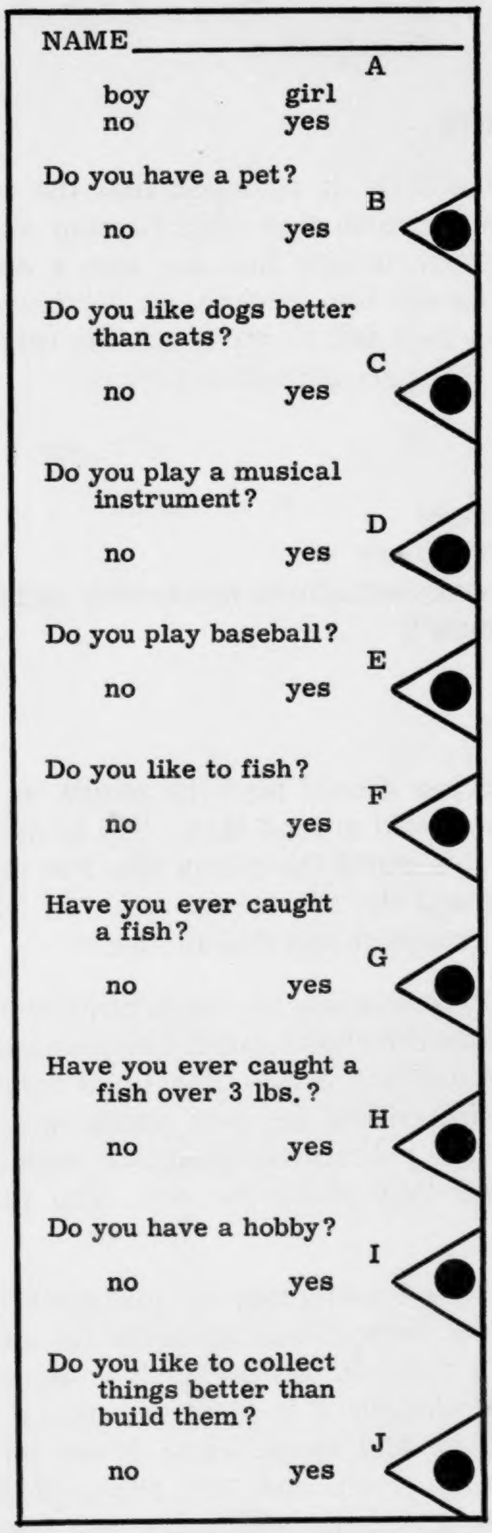
Materials

knitting needles
cards carrying the copy at right

Procedure

Give one of these cards to each pupil in the class. Ask him to circle the correct answer to each question. As soon as this is done, take a paper punch and punch the circles for each *yes* answer. For each *no* answer, cut out the V with scissors.

Have the pupils organize the cards alphabetically. Relate to the pupils that they have been classified according to the answers they gave to the questions. Show that it is possible now to ask questions such as: How many pupils play a musical instrument? How many play ball?



NAME ______________

A
boy girl
no yes

Do you have a pet?
B
no yes

Do you like dogs better than cats?
C
no yes

Do you play a musical instrument?
D
no yes

Do you play baseball?
E
no yes

Do you like to fish?
F
no yes

Have you ever caught a fish?
G
no yes

Have you ever caught a fish over 3 lbs.?
H
no yes

Do you have a hobby?
I
no yes

Do you like to collect things better than build them?
J
no yes

Encourage the pupils to ask these questions. Then let them insert a knitting needle through the card pack for the question asked and pull out the yes answer cards. With two knitting needles, more than one question can be asked at a time.

Lead the pupils to see that this type of coding could be done in a library with books, in a laboratory for different chemical reactions, by a biologist for coding the plants that live in a certain area, etc.

CONCEPT: Classification schemes are man-made and often do not conform to nature.

ACTIVITY 1. Problems in Plant and Animal Classifications

Introduction

In this activity it is hoped that the pupil will be led to conclude that classification systems do not represent nature but are man's attempt to organize nature into meaningful relationships. Inasmuch as they fail to represent the relationships of nature, they are not without error.

Materials

- bread slices
- tight containers
- mushrooms (sometimes incorrectly called "toadstools")

Procedure

The teacher should lead the pupils in a discussion of the world around them. Try to develop the idea that this world fits nicely into two categories, the living and the non-living. Ask, "In what ways are these groups subdivided further?"

There are several ways to subdivide the non-living world. Guide the class toward discussing the living world and dividing it into plants and animals. Ask how to differentiate between plants and animals. Someone will probably suggest that animals move around and that plants do not. Also plants are green.

Grow some bread mold by placing bread in a moist, warm, dark, closed container for a few days. Discuss the mold as to whether it is living or nonliving and whether it is plant or animal. While it is not mobile and therefore it is not an animal, neither is it green. Ask the pupils if they can think of other plants which are not green. Have samples of mushrooms for them to see, or ask them to bring in some of these.

ACTIVITY 2. Metals and Nonmetals

Introduction

The division of the elements into metals and nonmetals constitutes another of man's attempts to find relationships in nature. This activity will stress observation and comparison of properties and will emphasize two situations where elements do not fit the general classification scheme.

Materials

- copper
- lead
- iron
- zinc
- aluminum
- mercury
- sulfur
- iodine solid
- carbon (graphite in solid form)
- gases—oxygen and nitrogen, if possible
- 6-volt battery
- electrical wire
- 6-volt bulb and socket

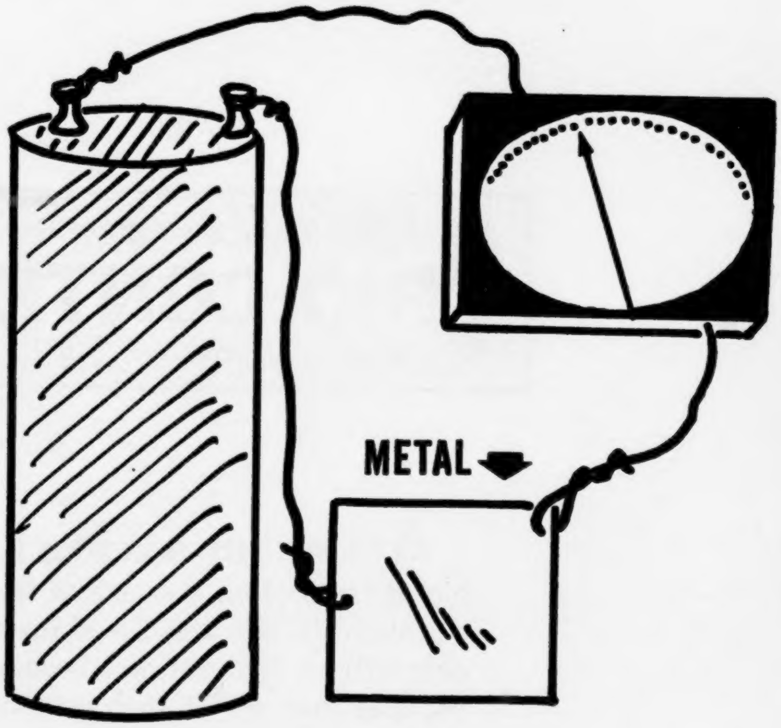
Procedure

Assemble the preceding collections of elements with the exception of mercury and ask the pupils to write down descriptions of each. Sandpaper the metals to remove their oxide coating. Put these in stoppered test tubes for safety's sake. When the pupils have finished writing, ask them to discuss the properties they have observed. Ask if they can suggest a basis for classification of the elements. They will probably suggest several, but lead them to the metal-nonmetal distinction. Be sure that they have the following properties of metals and nonmetals well in mind:

Metals	Nonmetals
ductile	brittle
maleable	gases and solids
solid	
luster color	

After having discussed metals, show them mercury. (*Caution: Mercury should be handled in a stoppered container. Special care should be taken to see that it is not spilled or left setting around in an open container. As long as it is contained, it is safe to use.*) Ask the pupils to describe the mercury. They should observe that it is a liquid. Ask if they think mercury is a metal or a nonmetal. Lead them to see that mercury is a melted metal and its appearance is not different from that of other metals above their melting point. Another property of mercury which will stand out is its density (weight/unit volume). The concept of density will probably be beyond the pupils at this point. They will probably say that it weighs a lot.

Set up a battery with three wires as indicated in the diagram. Test to see if metals conduct electricity by touching the two loose ends to the samples. Be sure to test mercury. The light will shine when appreciable current flows. Neither sulfur nor iodine will conduct, but graphite will. Show that on the basis of color and brittleness, graphite would have been classed as a nonmetal, but on the basis of conductivity it falls into the metal category.



EVALUATION

Most evaluation of this material should be done during the course of the unit rather than at the end. The terminal evaluation should be in terms of the objectives. Pupils should be able to describe the values of the scientific process of classification. Secondly, they should be given an opportunity to set up a classification system for a collection of objects. Thirdly, they should be able to use a key to classify an object. Probably most important of all, do not expect them to recall the facts that have been presented in this unit.

BIO-CONTROL SYSTEMS

ALL OF THE SCIENTIFIC SKILLS are needed to study any biological system because of the diversity and complexity of such a system. In this unit the skills of *observing, inferring,* and *recording data* will be stressed, not because they are the only ones used, but because they are of such primary importance in this type of study. These skills should be emphasized through pupil activities in which the pupils will work with, study, and observe living organisms and systems of organisms.

Unit Goals

Upon completion of this unit the pupil should be able to:

1. Recognize the changing nature of any biological environment.
2. Identify the gross components of a large biological community.
3. Recognize and identify plant and animal responses to stimuli and infer the reason for the response.

Unit Development

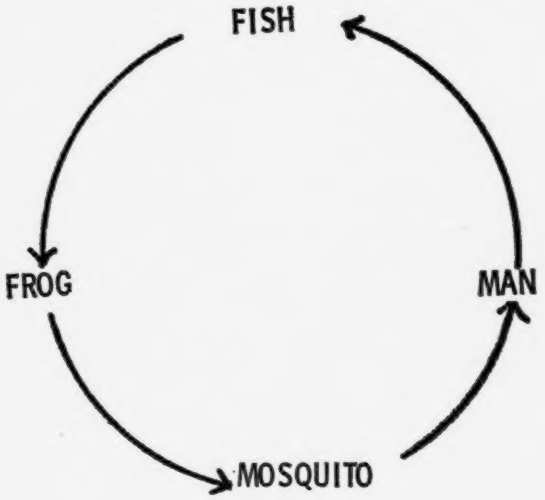
This unit can be initiated with a discussion of the dependency of living things on other living things such as:

1. Flowers depend on insects for pollination.
2. Fish depend on small animals for food.
3. Cows depend on plants for food.

From this discussion the idea of a food chain should develop, and the teacher can record this on the blackboard.

Some questions that can develop from this diagram are:

1. Are fish the only thing that people eat?
2. Are frogs the only things that fish eat?
3. Are mosquitoes the only things that frogs eat?
4. Do mosquitoes feed only on people?



The pupil will soon become aware of several key points:

1. Simple food chains are only general.
2. Biological systems are very complex and interdependent.
3. Plant life cannot be ignored when considering any biological system.
4. Certain controls work in any system.
5. Energy is derived from the sun.

From these key points the unit may be developed in several directions.

CONCEPT: **All living things are dependent on other living things plus a source of energy from outside the system.**

This concept can be developed through the use of an aquarium in the classroom. It is important that the pupils themselves participate in the actual setting up of the aquarium.

ACTIVITY 1. Setting Up and Observing a Balanced Aquarium

Introduction

A balanced aquarium is an excellent way to study a biological control system. It is a closed eco-system dependent only on an outside source of food.

Materials

tank from 2 to 10 gal.
tank heater
thermometer
gravel
plants
fish
snails
net

Procedure

This activity should be started with a field trip to a nearby pond, lake, or stream. Before the field trip, a class discussion should establish some major objectives for the trip, such as:

1. To observe a natural aquatic environment.
2. To identify and elevate the parts of that environment, i.e. fish, snails, plants, water, air.
3. To collect samples of water, plants, and animals to be observed in the classroom.
4. To infer the most likely outside sources of energy that enter that environment.

Upon returning to the classroom, examine the samples that have been collected or put them in a safe place for examination during the next class period. Things to look for include the basic structure of plants and animals and how they compare with similar structures in terrestrial plants and animals.

With this background, have the class start setting up their aquarium. This should be done over a two-week period with other activities interspersed. While the aquarium is being set up, the pupils should be encouraged to do research of their own on the subjects of aquaria, fish, aquatic plants, and aquatic life in general. Pupils should make daily observations of their aquarium and record them.

To support and add to the understanding of the classroom aquarium and the pond or stream which was visited, carry out the following activities while the aquarium is being set up:

ACTIVITY 4. Collecting Oxygen

Introduction

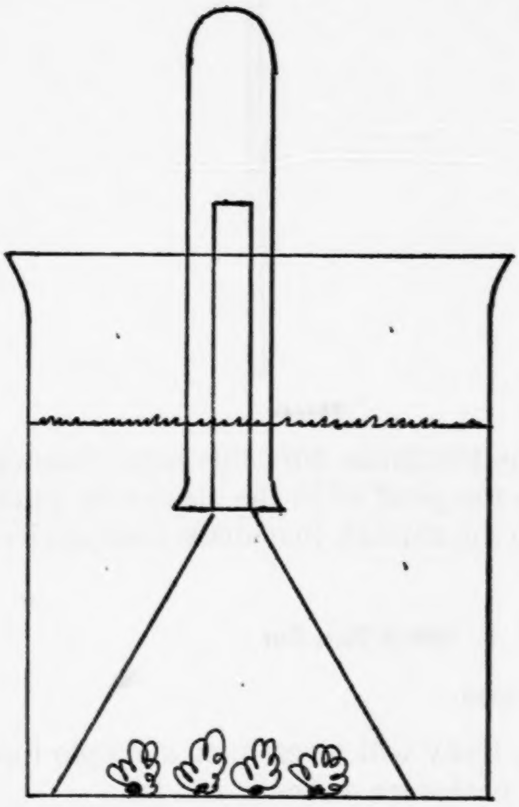
Plants use carbon dioxide and water to produce sugar. A by-product of this process is oxygen. In this activity we will try to collect and identify this gas.

Materials

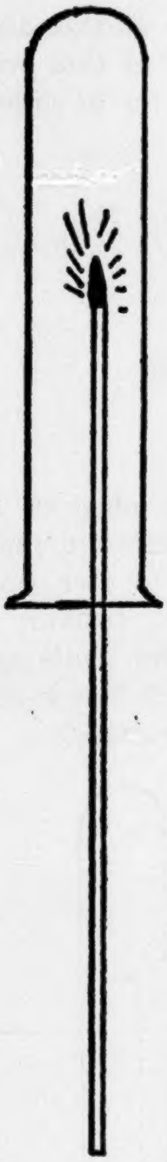
beaker (400 ml.)
glass funnel
test tubes
elodea water plants
wooden splints

Procedure

To measure and observe the production of oxygen by a plant through photosynthesis, divide the class into four or five groups. Provide each group with a 400 ml. beaker, a glass funnel that will fit into the beaker while upside down, a small test tube, and a small bunch of elodea (an aquatic plant available at pet shops).



Fill the beaker with water, place the elodea in the bottom, and cover with the large end of the inverted funnel. Over the small end of the funnel, place the inverted test tube, making sure it remains full of water. Place the whole system in bright sunlight and observe what happens. When the test tube is about half filled with gas ask the pupils to infer what the gas is. To test the gas, have the pupils insert a glowing piece of wood into the test tube; if the gas is oxygen, the wood should glow very brightly for an instant.



What implications does this have concerning the plants in the pond or in the classroom aquarium in regard to the animals that share their environment?

ACTIVITY 3. What Fish Eat

Introduction

This activity will investigate a simple food chain of algae, protozoan animals, and fish.

Materials

guppies
pond water
beakers (1,000 ml.)

Procedure

With some of the pond water brought back from the field trip, fill two 1,000 ml. beakers or wide-mouth jars of about that size. Put guppies in each jar; set one in direct sunlight and one where it will not receive any direct sunlight. Observe the fish in the two jars for a period of three or four weeks.

Record such things as:

1. Growth, if any.
2. General condition of fish.
3. Microscopic organisms in water (with microscope).

After the fish in both beakers have been observed and the data recorded for a period of three or four weeks, have the class draw inferences that will explain the results.

ACTIVITY 4. A Closed System

Introduction

The relationship between plants and animals can be shown on a small scale in this activity.

Materials

test tubes
rubber stoppers
pond snails
elodea water plants
pond water
paraffin wax

Procedure

Instruct each group to fill two test tubes to within one inch of the top, put a pond snail in each test tube and the branch of elodea in one of the test tubes.

When this is finished, have the groups put the stoppers into the test tubes and label each test tube with the group number and what went into it.

The test tubes should then be set together in one part of the classroom and observed. Each group should make its own observations, recording when each snail dies. When the last snail has died, the data should be pooled and discussed. What inferences can be drawn?

CONCEPT: Every organism responds to its environment.

To begin developing this concept, discuss how humans respond to their environment. Some points that could be discussed are:

1. What do humans do when they are hungry?
2. What do humans do when they are too hot or too cold?
3. What do humans do when they are thirsty?

From this discussion the pupils should realize that all living things have certain needs and that the organism will respond in a way which tries to satisfy these needs.

ACTIVITY 1. How Fish Respond to Their Environment

Introduction

This activity will show one of the many ways in which animals respond to stimuli from their surroundings.

Materials

goldfish
beakers (400 ml.)
thermometers
candle

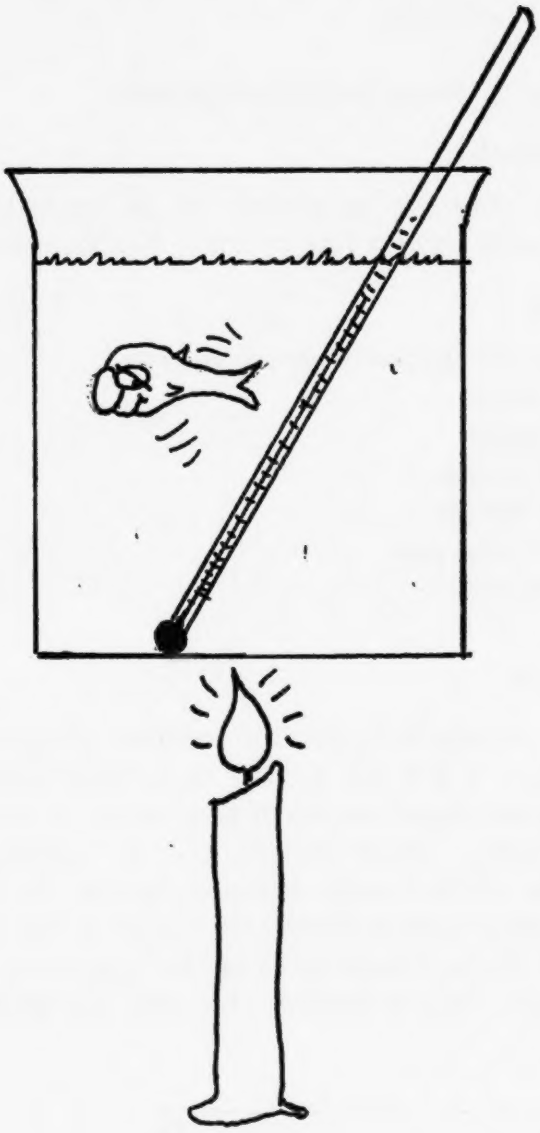
Procedure

Arrange the class into four to six groups and provide each group with a 400 ml. beaker or a wide-mouth jar of about that same size, a goldfish, a thermometer, and a candle. Have each group fill the beaker with water which has been allowed to sit overnight, and add the goldfish.

Now, with a person appointed as recorder for each group, have the pupils put the thermometer into the water with the fish and record the temperature. At the same time, have the pupils record the number of times the fish beats its gill plates (the outer covering over the fish's gills) in one minute (the teacher will probably wish to call out the time for the whole class).

With these data recorded, have the pupils heat the water slowly with a lighted candle until the temperature has been raised about five degrees. At this time have the pupils make a new observation of temperature and gill plate beats and record the results. Continue this process of raising the temperature by five-degree steps until a temperature of not more than 100 degrees Fahrenheit is reached. This will not hurt the fish if the temperature is raised slowly.

Throughout this experiment the behavior of the fish should be observed, e.g. speed at which it swims about. When the experiment is finished, have a spokesman from each group report the results and conclusions. Finish this activity with a class discussion to pull the class's conclusions together.



ACTIVITY 2. How Fish Find Food

Introduction

Fish, like many other animals, can learn simple responses to stimuli. This activity will show one of those ways.

Materials

goldfish
bowls
fish food

Procedure

The same groups that worked together in the previous activity should now place their fish at some spot in the room which has been assigned by the teacher. Instruct the groups to feed their fish every day at the same time and to tap the side of the beaker just before adding the food. Have them do this for a period of three or four weeks and record all observations they make. At the end of that period have each group report its results and conclusions. Ask them to what stimuli they think the fish responded.

ACTIVITY 3. Plants Respond to Stimuli

Introduction

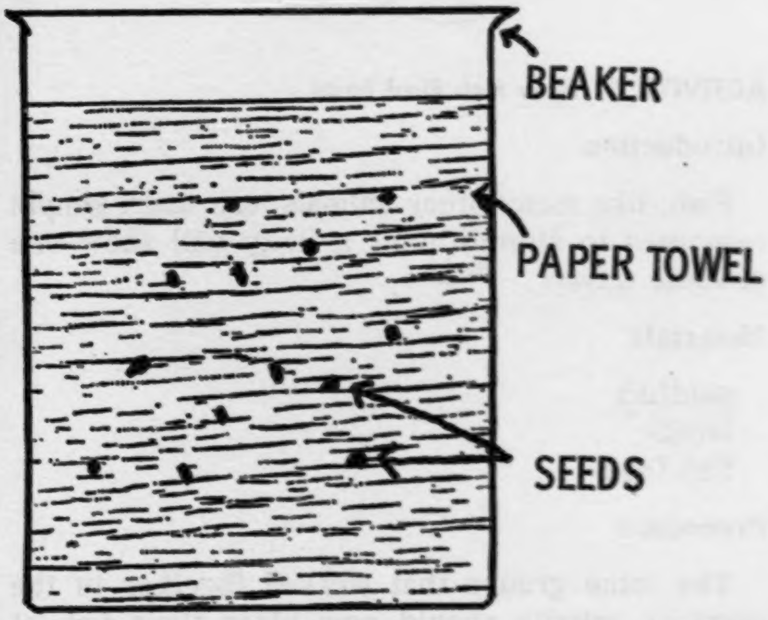
Plants respond to stimuli as do animals. This activity will show a few of these simple responses.

Materials

200 ml. beaker or wide-mouth jar
bean seeds
corn seeds
radish seeds
paper towels
square cake pan
potting soil
water

Procedure

Again divide the class into several groups. Give each group a 200 ml. beaker or a wide-mouth jar of about the same size, some bean seeds, corn seeds, radish seeds, paper towels, and a square cake pan with potting soil. Instruct pupils to fit the paper towels snugly against the inside of the beaker with one of the seeds between the glass and towel. Have them fix one beaker this way for each type of seed.

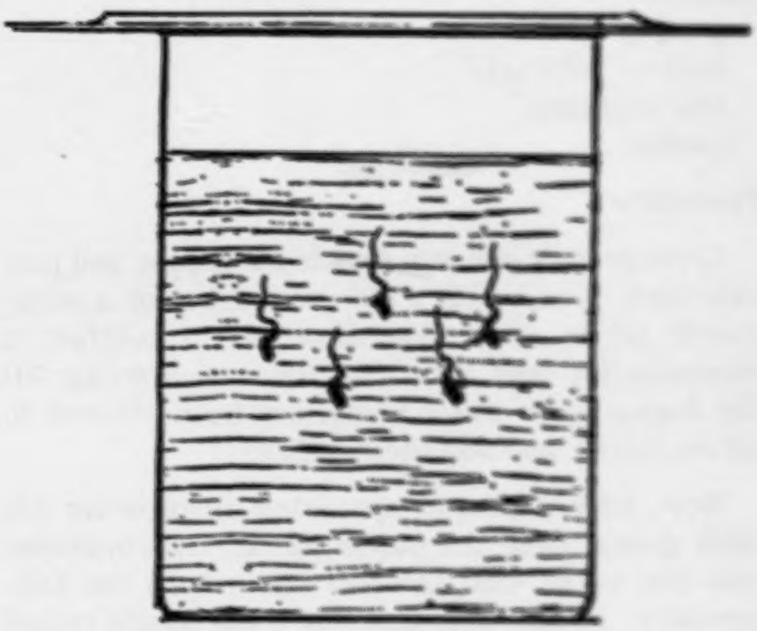


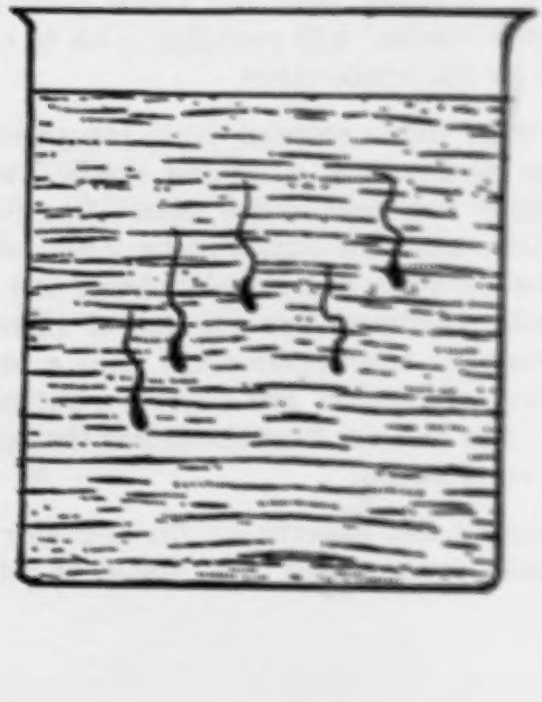
When this is set up, instruct the pupils to put about one-half inch of water in the bottom of each beaker (it is important that the towel always stays moist).

Have the pupils put these beakers up where they can add water every day and observe them. We will come back to these seeds.

Now have the groups plant some of each kind of seed in the square cake pans, using potting soil. Tell the pupils to plant one end of each pan thickly and one thinly, marking them. These pans should now be placed in a safe, lighted part of the classroom and watered often.

After a few days or when the seeds have sprouts of from one to two inches long, have the groups turn their beakers upside down in a saucer which has about one-half inch of water in it. These should then be set back and observed along with the seeds which are in right-side-up beakers. After the beak-





ers have been upside down long enough for the sprouts to turn and start growing, ask the pupils to draw conclusions and make inferences.

By this time the seeds that have been planted in the cake pan should have sprouted enough to observe the effects of crowding. Have the pupils observe their pans and make inferences as to the cause and effect of the differences between the two ends of the pans.

ACTIVITY 4. How Plants Respond to Light

Introduction

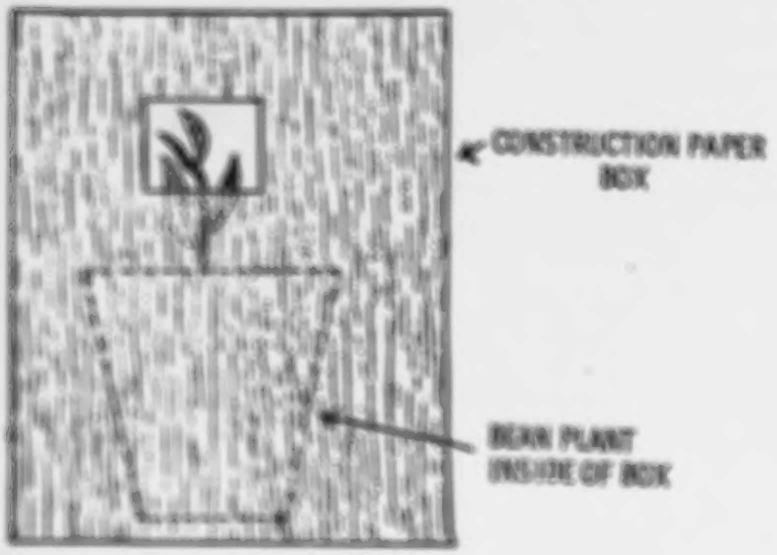
Plants, like animals, respond to their surroundings. This activity will show how plants respond to light.

Materials

bean sprouts
flower pots
construction paper

Procedure

With some of the bean sprouts from the previous activity, the class will be able to study the effect of light on plants. Have each group remove two bean plants without tearing off the root hairs and replant them in small flower pots. Now have each group make a box 10 inches high and six inches square from heavy construction paper. In one side, about four inches from the bottom, have them cut a one-inch square hole. This box should now be placed over the bean plant so that the only light the plant will receive will be the light coming through the hole in the side of the box.



This box should be lifted off every day when the plant is watered and observed. Results of these observations should be recorded at the end of four or five days, or when the plant has grown over toward the light. The results should be used to draw conclusions.

CONCEPT: A biological community is always changing.

This concept should be initiated with a discussion of changes which the pupil is familiar with such as:

1. What happens to a lawn if it is left uncared for?
2. What happens to a farmer's field if it is left unplowed?

ACTIVITY 1. Changing Biological Systems

Introduction

All biological communities are in a constant state of change. The activity will allow the pupils to see that change in a micro-community.

Materials

one gallon wide-mouth pickle jars
sheets of glass 6" x 6"
soil

Procedure

Divide the class into four to six groups and provide each group with one wide-mouth gallon jar and a sheet of glass. Have the pupils put about two inches of soil in the bottom of the jar. This soil should have been gathered by the pupils or the teacher from a variety of places. It should be the top one inch of soil taken from the floor of a wood, a pasture lot, and a ditch. Each group of pupils should have soil from a different area.

When the bottom of the jar is covered with two inches of soil, it should be wet down and the jar covered with a sheet of glass. After the glass is in place, the jar should be set in a safe location and observed daily.

The pupils should look for dominant species of mold, ferns, or green plants. A dominant species would be one present in the largest number.

From week to week and even from day to day the dominant plants will be changing. No two of these soil cultures will be alike, so each group should be allowed to share the other's observations.

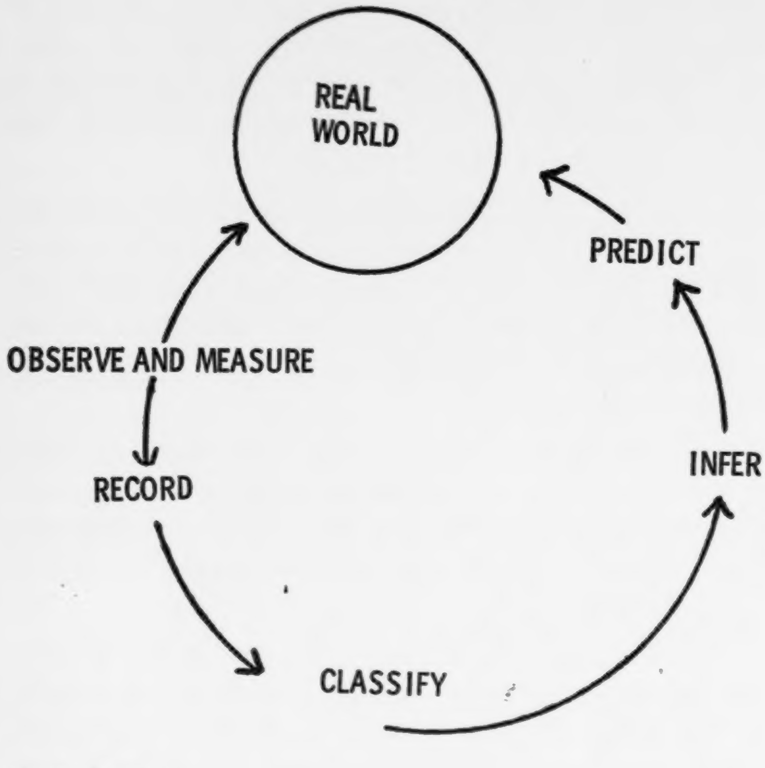
This activity should be culminated with a class discussion of the observations made.

EVALUATION

To evaluate this unit, the teacher should assign each pupil a written report to be done over a period of several days. In grading this report, the teacher should look to see if the pupil has visualized the "big picture" of biological systems and not be overly concerned with specific details. The teacher should see that the pupil understands and can use the skills stressed in this unit — *observing, inferring,* and *recording data.* Above all, a test of unrelated facts drawn from the material should not be used to evaluate this unit.

HYDROLOGIC SYSTEMS

THE BASIC SKILLS of observation, measurement, classification, the recording of data, and inference have been introduced and developed in preceding units. No doubt many pupils have attempted to foretell outcomes based on these developing skills. However, the power to predict accurately hinges on the observations made, measured, recorded, and classified. These processes result in inferences which may lead to significant predictions. Prediction is a logical and natural pupil activity, but it should be appropriately developed so the pupil recognizes it as something more orderly than the simple, haphazard guess.



Unit Goals

Upon completion of this unit, the pupil should be able to:

1. Understand the properties of water which establish it as an essential constituent of and an important determiner of our environment.
2. Identify the hydrologic system as a part of the more comprehensive interacting matter - energy system.
3. Make inferences and predictions concerning the income, storage, and outgo of water in the hydrologic system.
4. Identify water as an important and functional medium of living things.

Unit Development

In this unit, water is considered as an important and primary substance of the land, air, sea, and biosphere, and functions well within the matter-energy interaction scheme. All pupils will have had some experiences with water but may not have established its significance as developed in this unit.

Water may be introduced as a substance which occupies approximately 72 per cent of the earth's surface, represents up to 4 per cent of the composition of the air, and is a major constituent of all living things (about 60 per cent of the human body). Initially the pupils should realize the abundancy and common occurrence of water.

Although water is plentiful, it possesses properties which makes it unusual among earth compounds. The properties of water should be developed to establish it as a unique substance in our environment and unique in life itself. After the completion of the activities under concept one, a discussion should logically be developed concerning the pupils' observations in terms of the following topics:

1. What other material at or near the earth's surface normally exists in all three states of matter?
2. What is the relationship between the boiling and freezing temperatures of water and the temperature limits in which life can exist?
3. What would happen to the earth if water did not expand and become less dense but instead became more dense?
4. Why doesn't salt water freeze like fresh water?
5. What effects would develop on the earth and on living things if water did not dissolve solids and gases?

After this initial unfolding of the properties of water, pupils should be formally introduced to energy as the necessary ingredient for activation of the processes within the hydrologic system. This section readily lends itself to the continual interaction of matter and energy and the resultant changes within a system. Most pupils will associate water with its liquid state, for this is most common to their day-to-day existence. Pupils may then question how water can exist in three states at or near the earth's surface.

How can water change from one state to another? Evaporation and condensation are established as the processes involved in the change from one state of matter to another. The teacher should initiate a discussion which will put these activities into proper perspective for the pupil in terms of real earth conditions. The discussion should lead to pupil inferences concerning the heating of water on the land and seas, the source of energy which causes evaporation of water to form water vapor, and the relationship of temperature to evaporation.

Does the evaporation process always require a boiling temperature? Can water evaporate in the winter?

The condensation process is developed in an activity to establish a definite relationship between water vapor and energy. By means of this activity, pupil inferences are directed to the condensation process in the atmosphere. How does cooling of the air take place? What energy change must occur for water vapor (gas) to become a liquid?

After this section, the pupils might possibly formulate inferences concerning the income, storage, and outgo of water within the hydrologic system. Water enters the air through evaporation, is stored in the air, and will leave the air upon condensation. This will mark the beginning of pupil thought regarding the cyclical nature of water in this system.

After directing the pupils' thoughts to the evaporation and condensation processes, we now turn to water and its relationship to weather. Weather is very important to the pupils, and water is a significant determiner of the weather. Water is commonly associated with clouds, various forms of precipitation, and humidity. However, an attempt is made in this unit to establish water as a moderating influence on the earth's climate. The remarkable property of water which causes it to heat slowly and give up heat slowly is emphasized. If it were not for the water vapor in the air, the earth would be terribly hot during the daytime and bitterly cold at night.

The unequal heating of land and water and its relationship to air movements may be developed as the teacher sees fit. However, the ability of water to take in a great deal of heat and to hold on to it should be stressed as a moderating factor in the climates of the world.

Ocean currents are portrayed as mechanisms for the transport of heat energy and important moderating influences on climate. Warm and cold currents in the oceans again direct attention to the interaction of matter and energy within the hydrologic system.

The activities involving the formation of dew, frost, fog, and clouds serve as vehicles for illustrating how water leaves the air. They are also the most common pupil associations regarding water and weather.

The teacher should direct the discussion toward the relationships between water in the air, dewpoint temperature, and the various forms of precipitation. Other types of precipitation (snow, sleet, hail) may be introduced at the teacher's discretion.

Attention is now given to the importance of water in the biosphere. Stress the significance of water as the chief substance of the living cell and the properties of water which define the functional limits of living things.

The final phase of this unit serves to illustrate the cyclical nature of the hydrologic system. The properties of water; the processes of evaporation, transpiration, and condensation; and the forms of precipitation should be related in terms of the income, storage, and outgo of water within the hydrologic system. Emphasize the fact that energy is the regulating factor in the water cycle.

CONCEPT: Water has certain properties which make it unique among compounds.

ACTIVITY 1. Boiling and Freezing Points of Water

Introduction

Two of the unique properties of water are its boiling point and its freezing point. It is within the confines of these two temperatures that most of life on earth is required to exist.

There are many misconceptions about these temperatures and what is happening physically at these temperatures. The pupils will probably be aware that the boiling point is that temperature at which a liquid changes to a vapor. They may not be aware that when pure water boils the temperature remains constant once the boiling point has been reached.

They will be interested in observing at the opposite end of the temperature scale, that the freezing point of water is that temperature at which both liquid and solid exist at the same time. They probably are not aware that as long as both states are present, the temperature will remain at zero degrees centigrade. This activity is designed to lead them to make these observations.

Materials (per group)

1,000 ml. pyrex beaker, battery jar, or quart pan
100 ml. pyrex beakers
salt
ice
2 centigrade thermometers
burner
ring clamp
ring stand
wire gauze
distilled water

Procedure

Ask: What happens to the temperature of water when we heat it? What happens to the temperature when it is heated past boiling?

Part A—Divide the class into four or five groups. Direct each group to set up a ring, ring clamp, and burner. Place a 100 ml. beaker with about 50 ml. of distilled water in it and begin heating. Mark the level of the water on the side. Record the temperature every 30 seconds.

Direct one person to watch the second hand on the clock and call "time," have one person read the thermometer, and let the remainder of the class record the data. Direct the pupils to subtract each temperature from the one following it to determine the amount of change in temperature for each time period. Have each pupil record the temperature. Keep a record of the subtractions. Direct the pupils to take six to eight readings after the water starts to boil.

The teacher should lead a discussion of the results the pupils have observed. Their data should show similar temperature changes per 30-second period except as the temperature approaches the boiling point, at which time the changes should decrease to zero.

Ask the pupils to describe what happens when water is heated. They should be led to see that the data they recorded indicates that the temperature increased to a point and then stopped changing.

Ask if anyone knows why the temperature stops changing at the boiling point. This is a question they may not be able to answer. Lead them to see that the change of state was occurring at this temperature and also suggest that the heat being added here is not going into temperature change but into change in state.

Ask them to check the level of the water in the beaker after it stops boiling. There should be some reduction in the water level even for this short time. If not, boil for a longer period and recheck. Ask them where the water went.

If time allows, direct the pupils to start the water boiling again and to watch the bubbles this time. Direct them to observe where the bubbles rise and what happens to them as they rise. Ask the pupils what the result would be if they heated the beaker at a faster rate. Send them back to their stations and ask them to take the same type of data they took before but heat the water faster. While the changes per 30 seconds will be greater, the same temperature will be reached. Remind them to check the level of the water before and after heating and to compare what they observe. They should note that for the same amount of time more water boils away at the faster rate of heating.

Ask the pupils what they would do if they wanted to cook potatoes faster in an open pan on the stove. Some may still be tempted to say they would turn the burner up. If they do, ask the other members to comment on this. If they do not arrive at this conclusion, remind them that the water boils at a fixed point and that if they turn up the burner, more water boils away but the potatoes remain at a constant temperature and hence cook no faster.

Someone will probably suggest putting the potatoes into a pressure cooker. The teacher may suggest that a pressure cooker cooks faster by causing the water to boil at a higher temperature.

Use one set of pupil data to plot a temperature line graph on the board or overhead projector. Plot time on the horizontal axis and temperature on the vertical axis. Sample data and a graph are given below to help the teacher. Do not just copy these data; use pupils' data.

Time Min.: Sec.	Temperature
30:00	23°
30:30	30°
31:00	37°
31:30	46°
32:00	55°
32:30	64°
33:00	74°
33:30	85°
34:00	94°
34:30	100°
35:00	100°
35:30	100°
36:00	100°
36:30	100°

Part B—Ask if anybody knows how to freeze something. Some will say, "Put it in the freezer." Ask if there are other ways to freeze things. Ask if the pupils have helped freeze ice cream. Let them describe how this is done. Tell them that they are going to do a similar thing in this activity.

Provide the pupils with a large beaker, a battery jar, and a small 100 ml. beaker. Ask them to put about 50 ml. of distilled water in the small beaker and record its temperature. Ask them next to put ice in the large beaker and add salt. (Crushed ice will work faster than cubes.) They should put the small beaker down into the large beaker with the thermometer in the small beaker.

Direct the pupils to observe the formation of the ice on the surface. They should continue taking temperature every minute until they reach 0°C, then record the temperature every five minutes. It will be necessary to thaw the thermometer loose. They should observe that the temperature of the distilled water will drop slowly but constantly to about 0 degrees. There, it will stop changing. If the temperature of the salt-ice solution is low enough, the temperature will continue down after the distilled water has frozen.

Stress the observation that the temperature drops to zero and does not change for a time, and after it has frozen, it drops again. Ask: When the temperature reached zero did the water suddenly change to ice? Lead them to conclude that both ice and water were present at the same time and that the liquid is gradually converted to solid.

Once the temperature has reached zero degrees this activity will take some time to complete. The teacher will wish to start early in the day and ask two pupils to record data from the zero degrees point on until the thermometer is frozen solid. Additional ice may be needed, and some of the salt solution may have to be removed. Since the process is slow, pupils should take data every five minutes from the freezing point on.

ACTIVITY 2. What Happens to Water When It Freezes?

Introduction

When water freezes to form ice, the water molecules expand. Pupils, by direct observation, should be able to establish this principle as a property of water.

Materials

empty tin can, milk carton (pint size), or glass jar
water
freezer or refrigerator

Procedure

Fill the container (use different types of container to show different effects) with water so that the water level and the top of the container are the same. Place the container of water in the freezer or freezing compartment of the refrigerator. Freeze the water.

As the water freezes, what happens to the space originally occupied by the water? How can this be explained? Does this same process occur under normal earth conditions?

ACTIVITY 3. Water As a Dissolving Medium

Introduction

One of the foremost properties of water is that it dissolves many materials. This activity is not aimed at determining how much of a substance is, or can be, dissolved in water. The aim is to have the pupils discover that some things dissolve very well in water and others do not.

Materials

test tube rack
5 large test tubes and 5 rubber stoppers to fit
cooking oil
salt
1,000 ml. beaker or quart pan
sand
alcohol
sugar
centigrade thermometer

Procedure

Part A—Divide the class into four or five groups. Give each group a test tube rack and test tubes. Direct them to place 10 ml. of water in each test tube and to add a teaspoon of each of the following: cooking oil, salt, sugar, sand, and alcohol. Ask them to stopper the tubes and shake each tube five times and then let the tubes sit and record what they observe. After the tubes have sat for a while, ask the pupils to shake those which did not dissolve to see if further dissolving occurs. The oil should dissolve and sand will not, but the salt, sugar, and alcohol will dissolve. Discuss the results. Ask if gases dissolve.

Part B—Give each group a 1,000 ml. beaker or a quart pan and heat it gently. When bubbles form on the sides, stop heating. Ask what causes these bubbles. Some will say boiling. Take a thermometer and measure the temperature. Is is boiling? (No.) Lead the pupils to conclude that the dissolved material is air, and that when the liquid is heated the bubbles of air form because gases are not very soluble in water at high temperatures.

ACTIVITY 4. Capillary Action

Introduction

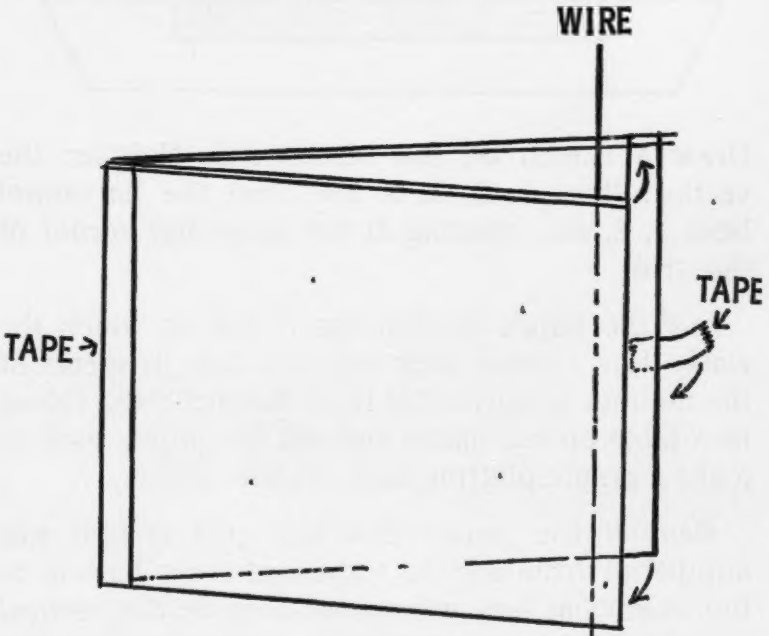
A unique property of water is that it sticks to things and to itself. This is called capillary action, and it is partly responsible for the rise of liquids in plants, vessels, and small cracks in rocks.

Materials

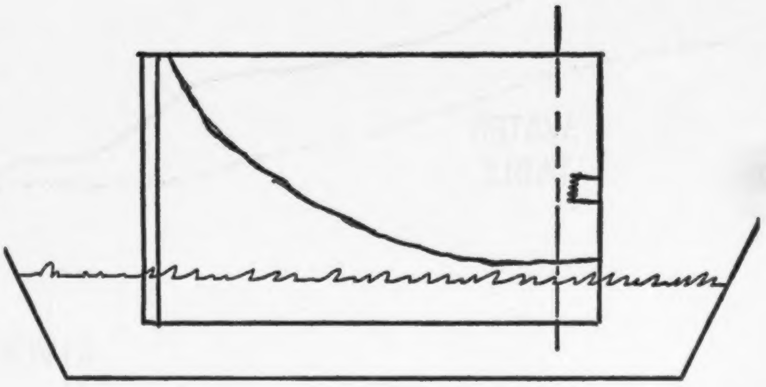
1 plastic dishpan
2 glass plates at least 10" x 12"
masking tape
small wire or 2 razor blades
3 or 4 different sizes of capillary tubing
1 triangular file (a regular saw file)
transparent grid
large test tubes
sand

Procedure

Part A—Pour some colored water into a large pan. Tape two edges of the glass plates together. Place a small wire or two razor blades between the other end of the plates as indicated below.

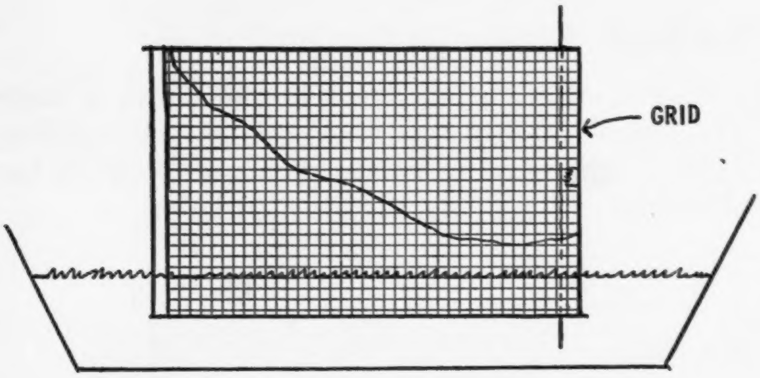


Lower the plates into a dishpan as indicated below. The water will rise. It may be necessary to lower the entire apparatus into the water in order to wet the surface, before holding it upright. Keep the top level. Ask the pupils to examine



the setup carefully and note that the water level changes from one end to the other. Ask: What causes this? Lead them to see that the closer the two glass plates, the higher the level of the water.

This is a good time to talk about graphing. This concept may not have been introduced yet but will soon be. Take a transparent grid such as is used on overhead projectors and tape it to one side of the plates as indicated below:



Draw a sketch on the blackboard. Number the vertical lines 1, 2, 3, 4, etc., and the horizontal lines 1, 2, etc., starting at the lower left corner of the grid.

Ask the pupils to find the height at which the water line crosses each vertical line in terms of the number of horizontal lines. Record these values in a table on the board and ask the pupils each to make a graph, plotting each of these points.

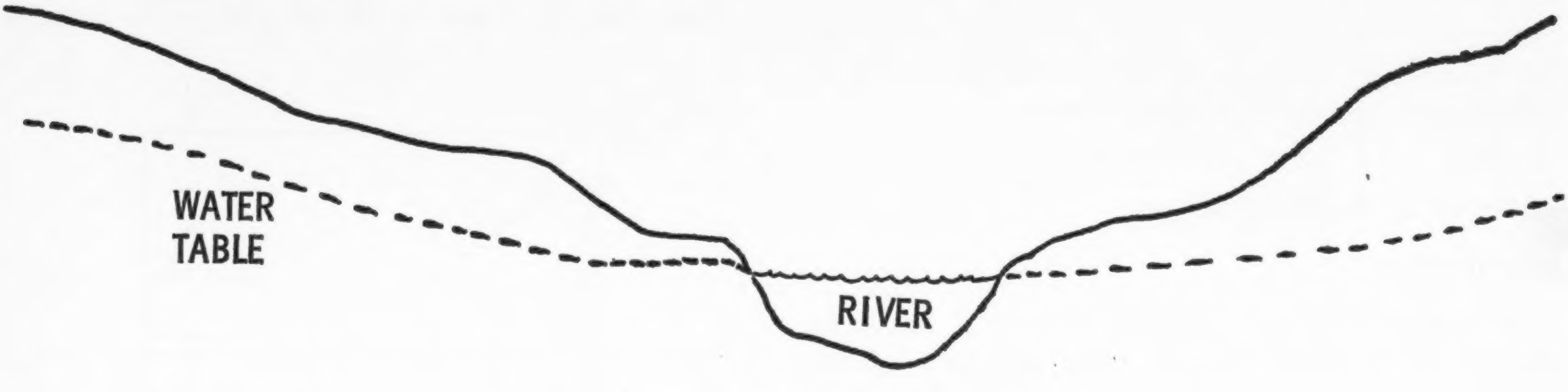
Remind the pupils that the grid system was numbered from left to right and from bottom to top. Ask what they were measuring on the vertical axis. If they do not suggest it, return to the setup and tell them they are measuring the height of the water at each vertical line. Ask what was measured along the horizontal axis? What is changing as we move to the right? Lead them to see that to the right the separation between the glasses gets larger, so that each vertical line represents a greater separation than the one before it. Thus, along the horizontal axis, distance between the glass is changing. Help them to conclude that a graph is a way of representing the changing in two properties.

In this case, the two properties are the height of the water and separation of the glass. Ask if they can describe the graph in a sentence telling how these two things change. Something like this is an acceptable answer: "The height of the liquid decreases as the separation of the plate increases."

Part B—Divide the class into four or five groups and give each group three different sizes of capillary tubes cut in four-inch lengths. (Cut glass tubing by first scratching across the tube with a triangular file, clasping the tubing in both hands, palms down. Place both thumbs at the scratch, then push away from the body with the thumbs while pulling back with the hands. Do not do this with someone in front of you.) Ask the pupils to consider the diameter of the three tubes and predict in which tube the water would rise the highest. Ask them to put the tubes into shallow water and test their prediction.

Part C—Fill large test tubes with sand. Fasten a piece of light-weight cotton cloth tightly over the top of the test tube with a rubber band to hold the sand in when the tube is inverted. Invert this in a shallow container and let stand for a period of time. Depending on the conditions, this experiment may take several hours.

At the same time, direct the pupils to invert a similar test tube without the sand in another container with the same depth of water. Ask what happened. Ask how the previous parts of this activity help us suggest a reason for this. Ask someone to make an application of what he has seen. If there are no suggestions, draw the following sketch: (Use either the board or the overhead projector.)



RIVER VALLEY CROSS SECTION

Ask if anyone has heard of the water table. Expect a variety of answers. Tell the class that the water table is an upper boundary of ground water below which all spaces in the rock are filled with water. People often dig wells down to this level. At the edge of a river or a swamp it coincides with the water in the river, but under the hills it rises. The reason it is higher under the hills is that capillary action is present in the sand and soil.

Ask what the pupils would expect if larger pieces of sand were used. If possible, contact a local contractor or gravel pit operator to get several different sizes of sand, and try the experiment in constant diameter tubes with different grades of sand. If this is not possible, the pupils should be able to suggest that the larger the grains of sand, the larger the openings between them, and the larger the openings, the lower the predicted level due to capillary action.

Return to the original experiment and ask how high the water rose in the tube with no sand in it. Ask if anyone knows why the class was directed to do this part of the experiment. Some may suggest that this is because they wanted to be sure that the capillary action in the sand and not the tube or the cloth was responsible. Tell them that experiments identical in every aspect except one (in this case the sand) are called control experiments. Scientists often use controlled experiments in order to be sure of their results.

CONCEPT: The natural processes in the hydrologic system require a flow of energy.

ACTIVITY 1. Heat Energy and Evaporation

Introduction

The purpose of this activity is to lead the pupils to discover the factors which are important in evaporation. The materials are simple. Maximum effort should be made to involve as many pupils as possible.

Materials

embroidery hoop
3 centigrade thermometers
rubbing alcohol
cooking oil
cotton balls
2 pyrex pie pans
2 100 ml. pyrex beakers
100 ml. graduated cylinder

Procedure

Part A—Place a spot of water on the chalkboard and direct the pupils to watch it until it disappears. Ask: What happened to the water? The pupils should conclude that it evaporates into the air.

Next make two spots of water on the board about the same size. Clamp a moist cloth in an embroidery hoop and hang it over one of the spots. Check to see which spot disappears first. Ask: Why does the open spot disappear first? The pupils should be led to conclude that moist air retards the evaporation. Ask if they can apply this to nature. Some may suggest comparing the rate at which a puddle of water evaporates on a "muggy" day or just after a rain with the rate on a dry day.

Place two spots of equal size at different places on the chalkboard as far apart as possible. Fan one with a sheet of paper and compare the evaporation rate with the other spot. Draw two lakes on the chalkboard as shown on the following page.

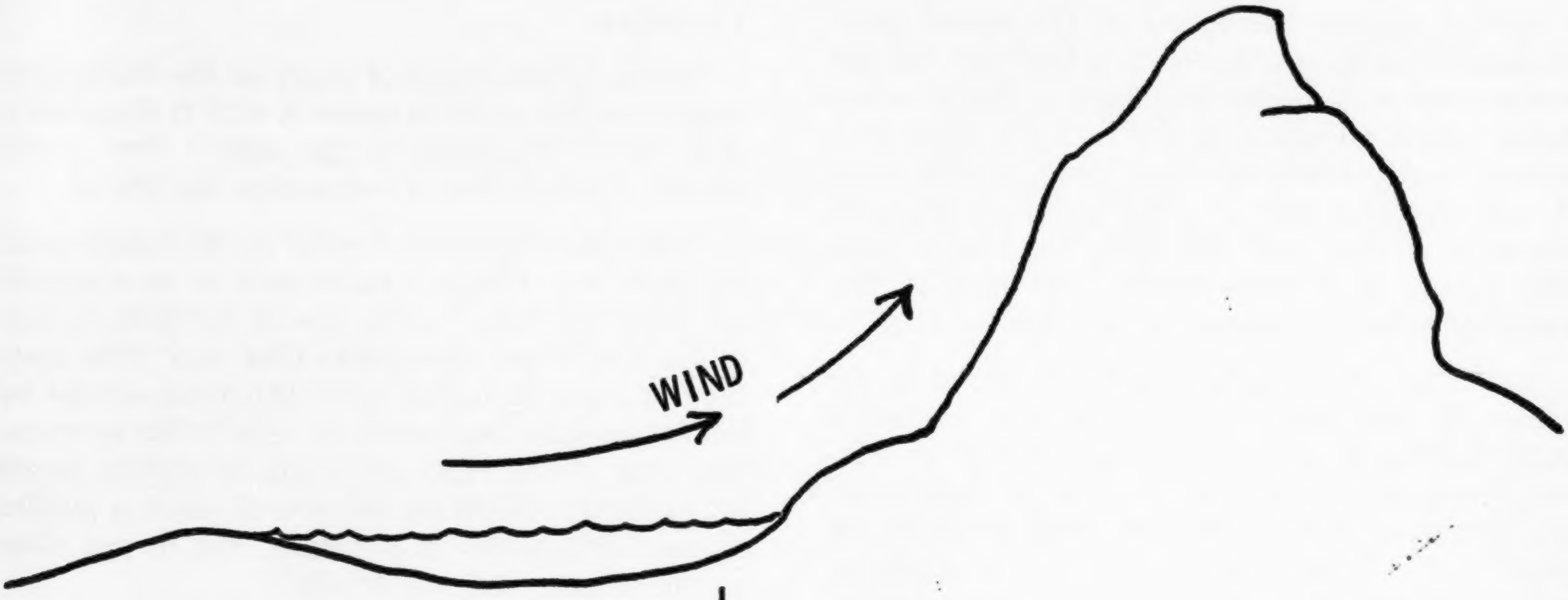
In the first drawing, the arrow represents a strong wind toward the mountain. The other drawing represents a similar situation with little or no wind. Ask: Considering the activity just completed, which lake will evaporate more quickly? What effect will this have on the mountain? The pupils should reason that if cooling causes condensation, then rain or snow or both will fall on the mountain as the water-laden wind moves up the mountain to the cold air.

Part B—Saturate one cotton ball with rubbing alcohol, one with cooking oil, and one with water. Squeeze out the excess liquid. All of these liquids should be at room temperature before the experiment is begun. Wrap each piece of cotton around the bulb of a different thermometer.

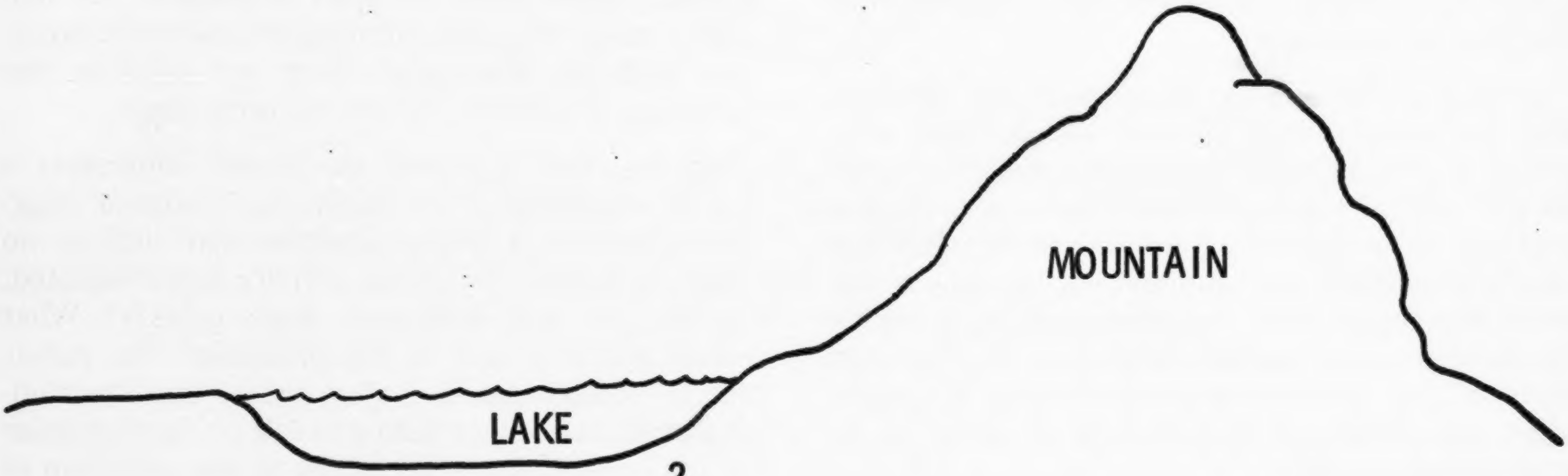
Place the thermometers close together so that all three can be fanned at the same time. Fan by moving a piece of paper over all three so that the air moves the same amount for each. Ask pupils to record the temperatures every minute for 5 to 10 minutes. Every pupil should record the data.

The alcohol will cool most rapidly, the water will cool more slowly than the alcohol, and the cooking oil will cool very slowly. Ask the pupils to explain the results. Lead them to conclude that evaporation is responsible for the cooling.

Someone may suggest that the three liquids were not the same temperature to begin with. If no one suggests this the teacher should suggest it. Have



1.



2.

the containers with lids in place nearby and ask a pupil to remove the lid, insert the thermometer, and report the temperature of each. They should all be the same.

Again ask the pupils how they would explain the results. Someone should suggest that not all liquids evaporate at the same rate. Alcohol evaporates most rapidly and cools most, while cooking oil evaporates so slowly that cooling isn't detectable.

Part C—Place one glass pie pan and a 100 ml. beaker in the warmest spot in the room. Place another glass pie pan and another 100 ml. beaker in the coolest spot in the room. Measure 100 ml. of water and pour into each. Let stand overnight.

Next day, using a graduate, measure the water in each of the four containers. Instruct the pupils to tell which evaporated most and which evaporated least of all four different containers. The warmest spot should show the greatest evaporation. Ask if anyone can tell why more water evaporated from the pie pans than from the beakers. Lead the pupils to conclude that the main difference between the two is the surface area: the greater the surface area, the faster the evaporation.

Summarize the results of the three parts. The following outline may help.

> In Part A, the class discovered that evaporation was faster (1) when the air had less water vapor in it and (2) when the air is moving.
>
> In Part B, the class discovered that (1) evaporation results in cooling and (2) different liquids cool at different rates when they evaporate.
>
> In Part C, the pupils discovered (1) the higher the temperature the faster the rate of evaporation and (2) the greater the surface area the faster the rate of evaporation.

Ask the pupils to devise an experiment in which water is evaporated at the maximum possible rate.

ACTIVITY 2. Condensation and Its Relationship to Energy Change

Introduction

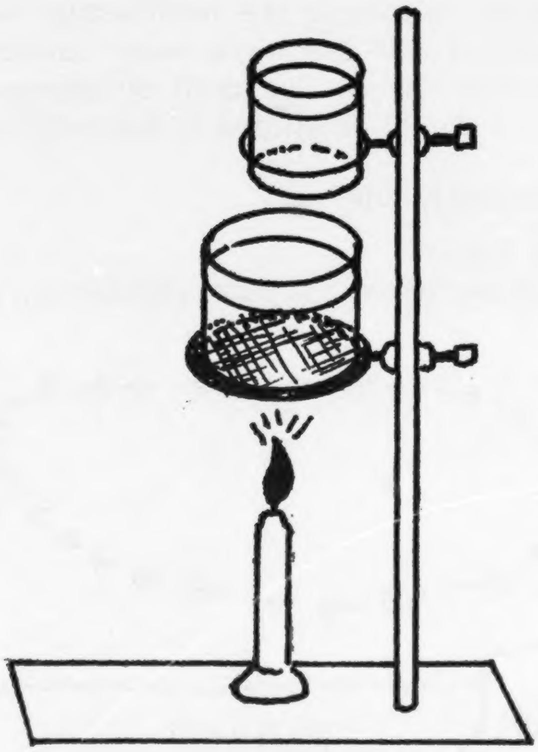
The relationship of condensation and energy change is important in understanding water in the atmosphere. The pupils may already know that water condenses on cool surfaces. In this activity, an attempt is made to lead them to see that condensation occurs when a gas loses heat energy.

Materials (per group)

small mirror
1,000 ml. pyrex beaker or quart pan
100 ml. pyrex beaker
250 ml. pyrex beaker (two of these)
centigrade thermometer
burner
ring stand
1 large ring clamp
1-3" ring clamp

Procedure

Part A—Support the large beaker on a ring stand over a burner. Support a 100 ml. beaker above it in a ring, as shown below.



Place tap water in the large beaker and heat to boiling. Put cold water in the small beaker and check its temperature before it is put in place over the large beaker. Then place it in the ring and begin heating the large beaker again. Heat to boiling. Note the condensation on the outside of the small beaker. Check its temperature every minute for 10 minutes. Discuss with the pupils their observation that the temperature of the cold water increases. Ask them to explain where the heat comes from. Lead them to conclude that the vapor gives up its energy to the small beaker as it condenses.

Part B—Give each group a small mirror. Ask one pupil in each group to breathe on the mirror and the others to record what they observe. Ask: What is the material on the mirror? Direct each group to set up two 250 ml. beakers, one with 200 ml. of warm water and one with 200 ml. of cool water. Direct the same pupil to breathe on the beaker with warm water and have the pupils note the lack of condensation. Ask why there is a difference. They will suggest that one is cold and one is hot. Lead them to see that another way of saying this is to say that in one instance the water vapor loses heat to the cold glass and, therefore, it condenses. In the case where the glass already has considerable heat, it does not reduce the heat of the gas and cause it to condense. Ask if anyone can suggest why he can see his "breath" on a cold day but not on a warm day.

CONCEPT: Water affects the weather.

ACTIVITY 1. Comparison of Land and Water Temperatures

Introduction

The heating of the earth involves solar energy and two fundamental materials—water and land. Through this activity the pupils should become aware of the moderating influence of water and the resultant effects on the weather. The pupils will be developing the skills of observation, recording of data, inference, and prediction.

Materials

2 equal size containers (milk cartons—cut in half, metal bowls, coffee cans, etc.)
2 thermometers (Celsius scale preferred)
black soil
water

Procedure

Have the pupils complete this activity in groups of four. They will be developing a model of earth conditions corresponding to water and land areas heated by energy from the sun.

Fill one of the containers with the black soil and the other container with an equal volume of water. Insert one thermometer in each substance. Place each of the setups in the sun. This should be outside if possible. If not outside, place on the window sill or use a 100- to 200-watt bulb as the heat source.

For best results in terms of the elementary pupil, let the soil and water sit overnight in the classroom so they are at the same temperature. This will mean that the pupil will have a common starting point for the temperature readings. Record the temperature every two minutes for 30 minutes. After 30 minutes have passed, take the setups out of the direct sunlight (place in shaded area or return to classroom). Again, record the temperatures every two minutes for 30 minutes. Make sure the setups are under similar conditions and the temperature readings are accurate.

Because land and water masses are heated and lose heat unequally, a discussion concerning the following topics would be appropriate:

1. Does soil or water heat up faster?
2. Do soil and water lose heat at the same rate?
3. How would the air temperature over a water mass compare with the air temperature over a land mass?
4. Would you rather be near water or land mass during the summer?
5. At night would the land or water lose heat more rapidly?
6. What is the relationship between the unequal heating of land and water and air currents? (Cold air moves in to replace warm air.)

Have the pupils infer and predict the effect of water vapor in the air on air temperature. They should reason that if water heats up slowly and stores the heat over a period of time, it should moderate air temperatures.

Discuss what air temperatures would exist if water vapor were not present in the air (earth would be hot in daytime, very cold at night). Would the water in the air give off heat at night as did the water in the activity when placed in the shade? Would the water in the air soak up the hot rays of the sun during the daytime?

Pupils should conclude that water stores heat and, therefore, has a moderating effect on the world's climate. The pupils may develop some understanding of the relationship between unequal heating of land and water masses and resultant air movements.

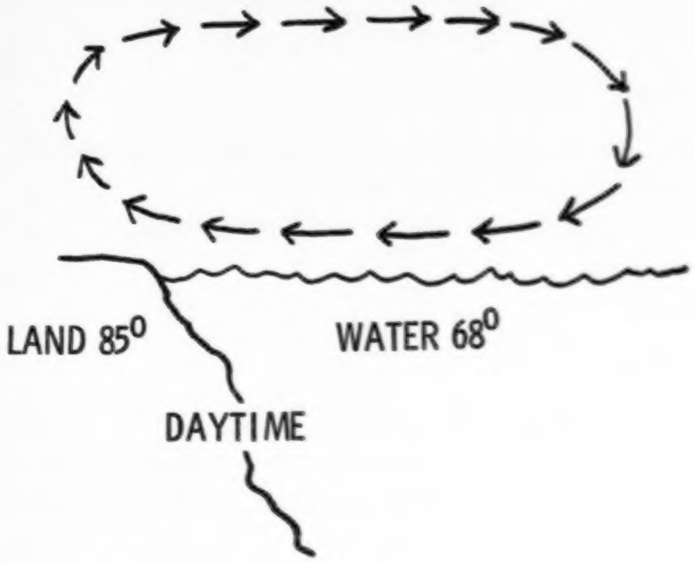
ACTIVITY 2. Ocean Currents and Their Effects on Climates

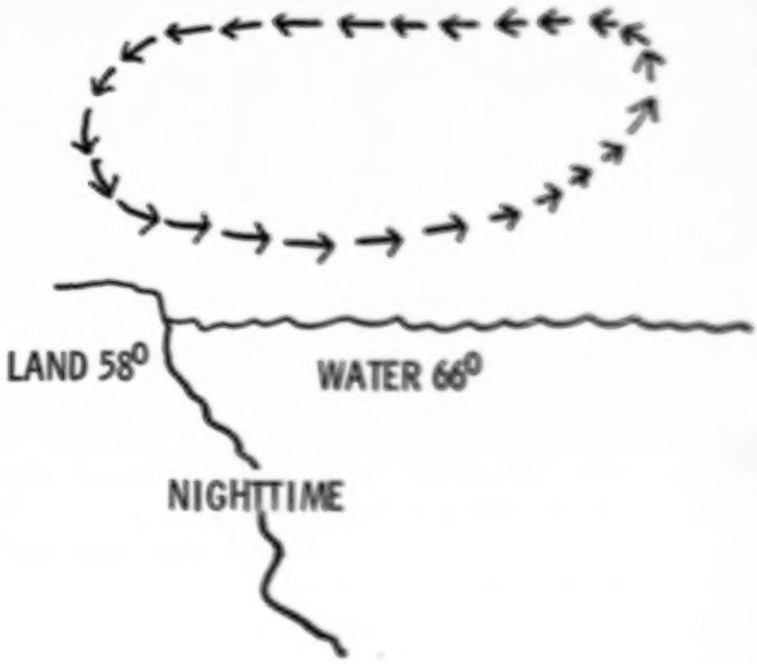
Introduction

Large flowing currents in the oceans are important as determiners of climate along the coastlines. This activity introduces the relationships between movements of cold and warm water currents and their climate effects. The skills of inference and predictions should be utilized in this activity.

Materials (per group)

2 coke bottles
warm water (warm tap water satisfactory)





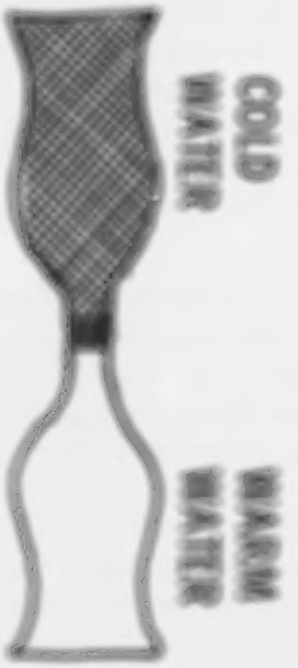
cold water (cold tap water satisfactory)
ink or food coloring
3" x 3" card (or paper towel)

Procedure

Groups of four to five pupils each are preferable for the completion of this activity.

Fill one of the coke bottles with warm water and the other with cold water. Add ink or food coloring to the warm water.

Place the 3" x 3" card on top of the coke bottle containing the cold water. Invert the cold water bottle and position it on top of the bottle containing the warm water. Remove the card and have the students observe and record the current flow.

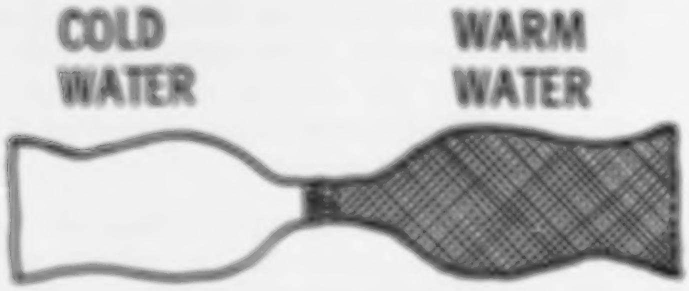


Discuss the pupil observations in terms of the following:

1. Do the currents flow in both directions?
2. In which direction does the colored warm water move? Why?
3. At what level would one expect warm water currents in the oceans?

Have the pupils make inferences based on the completed section of this activity and stimulate the formulation of predictions concerning results if the hot water is placed on top of the cold water (opposite of the first part of the activity). Develop the remainder of the activity on the basis of the pupil predictions. Direct the pupils to experiment and evaluate their predictions after the investigative process.

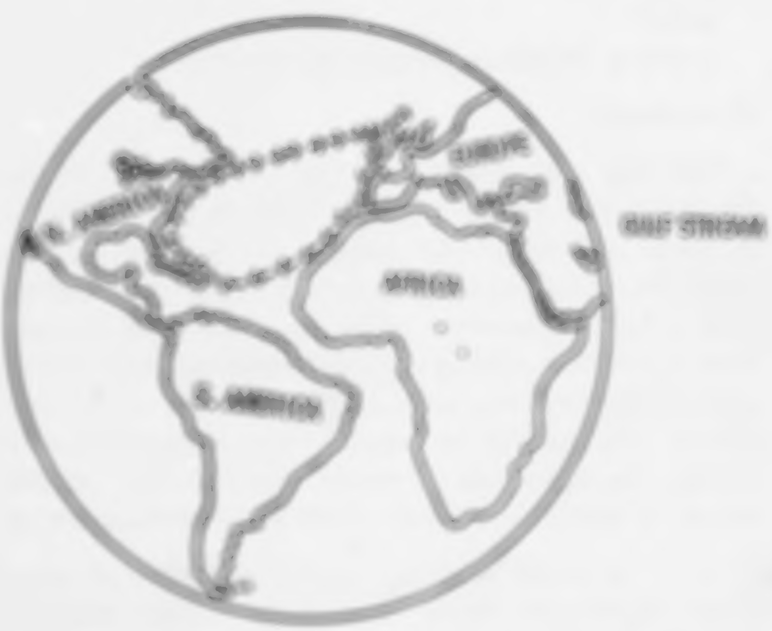
In which direction did the colored cold water flow? Why? At what level would one expect cold water currents in the oceans?



The teacher should demonstrate, in a more realistic fashion, the current flow when the two bottles are placed on their sides. First place the bottle of warm water on top of the colored cold water bottle. Pressing the bottles together, place them on their sides. Observe the current flow. This demonstration may give the pupils a better picture of current flow.

Discuss the results of this activity and their application to ocean currents. If the pupils do not suggest examples of known ocean currents, the teacher should mention the Gulf Stream, Labrador Current, Humboldt Current, or others. Elaborate on these currents in terms of these suggested topics:

1. Where does the heating of the Gulf Stream occur? (Believed to be caused by intense heating in the Gulf of Mexico.)
2. Why does the Gulf Stream flow at the surface of the oceans?



3. The Gulf Stream flows across the North Atlantic and strikes the shores of the British Isles and Northern Europe. What effect will

this current have on the climates of these geographic areas?

4. The Humboldt Current carries cold water from the Antarctic Ocean along the west coast of South America. What effect will this current have on the climate of this geographic area? Would this area be much warmer if this current were not present?

Hopefully this activity will stimulate pupil thought concerning water and its effects on climate. Emphasize the moderating effects of water on climate. Do not stress the recall of names of ocean currents or the specific areas they influence.

ACTIVITY 3. Formation of Dew and Frost

Introduction

Dew and frost are terms which are quite prevalent when speaking of the weather. This activity develops the importance of water in weather and will establish the relationship between condensation, dew, frost, and dew point temperature.

The activity should be done by the pupils in groups of four or five. The size of the group will depend on the availability of the materials.

Part A—Formation of dew

Materials

shiny tin can
Celsius thermometer
crushed ice
water
popsicle sticks or pencils for stirrers

Procedure

Fill the can about half full of water. Put the thermometer in the can and drop in ice a little at a time. (Caution the pupils to put in limited amounts of ice so they can determine an accurate dew point temperature.) Stir the water and ice mixture. Continue adding ice until condensation occurs and water droplets form on the outside of the can. Direct the pupils to record the temperature at which condensation occurs. Discuss the significance of this temperature (dew point temperature).

Why do water droplets form on blades of grass after nightfall? What are these water droplets called? During the summer months, why do we often find moisture on the grass in the late evening or early morning hours? Where does the water come from?

Part B—Formation of frost

Materials

shiny tin can
crushed ice
salt
Celsius thermometer
magnifying glass

Procedure

Form frost by packing the can with alternate layers of ice and salt. Three parts ice to one part salt will produce a temperature below 0°C. Pack the layers with a stick as the ingredients are put into the can. When the can is filled, place the thermometer in the center of the can. Pupils should observe and describe the substance which forms on the outside of the can and record the temperature at formation. Have pupils examine the frost with a magnifying glass. Discuss the temperatures at which frost and dew form. Under what conditions will dew form in contrast to frost formation? During the late fall, why does frost usually form instead of dew?

Extend this activity by discussing water vapor in the air at 1,000 feet above the ground in terms of the condensation process and the resultant forms of precipitation. Have the pupils imagine the conditions existing at this altitude. If dew were formed at 1,000 feet, what type of precipitation would be formed? If frost (ice crystals) were formed at 1,000 feet, what type of precipitation would be produced? What controlling factor determines whether snow or rain will be produced? (Note: This discussion involves an over-simplification of the basic principles involved but, hopefully, will cause pupils to make significant inferences and predictions.)

ACTIVITY 4. Formation of Fog

Introduction

Fog is usually a topic of curiosity to most pupils. This activity serves to illustrate the formation of fog. It builds on the activity of dew formation and dew point temperatures.

Materials

coke bottle
hot water (boiling)
ice cube

Procedure

Due to the risky nature of this activity, it might be appropriate to complete it as a demonstration.

Fill the coke bottle with very hot water. Allow the water to heat the bottle completely. Empty the bottle. Pour into the warm bottle boiling water to approximately the one-inch level. Place the ice cube over the mouth of the bottle. The sinking moist cold air should form fog when it strikes the water in the bottom of the bottle.

The discussion of this activity should include the following points:

1. What was formed at the hot water-cold air interface?
2. What is the possible relationship between the temperature at which dew forms and the temperature at which fog will form? (Fog forms whenever a mass of air is cooled below its dew point temperature.)
3. How are fogs formed? (When warm moist air flows in over a cold surface.)
4. Why do fogs commonly occur over the oceans and along the coasts?

This activity should indicate the importance of dew point temperature, condensation, and formation of fog. Emphasize that although fog forms at ground level, it is similar to the formation of clouds at higher altitudes. This idea leads into the study of cloud formation in the next activity.

ACTIVITY 5. Formation of Clouds

Introduction

Clouds portray a significant relationship between water and weather. Also, clouds are definitely part of an elementary pupil's experience. Therefore, this activity should establish some definite relationships between water, condensation, temperature, and condensation nuclei.

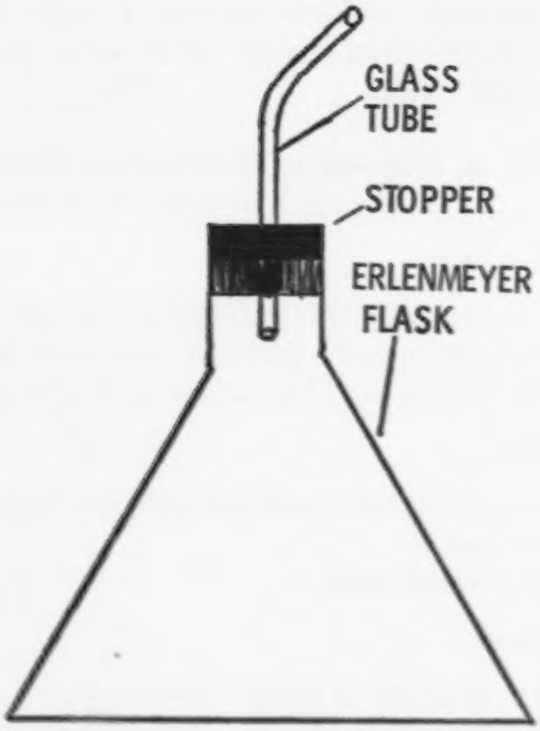
Materials

500 milliliter Erlenmeyer flask
one-hole stopper to fit the flask
glass tubing (6-8 centimeters in length)
rubber tubing (8-10 centimeters in length) which will fit the glass tubing

Procedure

Depending on the availability of the equipment, arrange the class in groups of four to six. This activity might also be done as a demonstration.

Clouds are formed when rising air expands and cools, causing condensation of water vapor on small particles (condensation nuclei). This activity is designed to simulate this process.



Pour enough water into the flask to cover the bottom of the flask. Insert the glass tube through the one-hole stopper and fit on the flask. Connect the rubber tubing to the glass tube.

Suck powerfully and suddenly on the rubber tubing. (The cloud can best be seen under diret light. You might shine a flashlight through the fask for best results.) A faint mist should appear.

The next step involves the introduction o smoke particles or chalk dust into the flask. These particles (condensation nuclei) provide the ncessary surface on which the water vapor can condense. Introduce these particles by removing the topper, lighting a match, blowing out the flame, ad then inserting the match into the flask or blowing the smoke into the flask. Shake or blow the chlk dust into the flask. Again, suck on the tubing.A definite cloud should form.

Discuss the types of particles that might be present in the air (dust and smoke). This discussion should emphasize the point that water vapr must have some substance for condensation (water droplets as in clouds, fog, dew, or ice in he case of frost.

Develop a discussion contrasting clouds nd fog. If questions originate concerning the coling of air to form clouds in nature, suggest tht rising warm air expands and as it expands it getcolder. What temperature is needed for condensation to occur? (Dew point temperature.) Do not dwell these two principles, as they require a more thorough understanding and ability than most pupils will have at this stage.

ACTIVITY 6. Instruments That Measure Water Vapor in the Air and Amount of Precipitation

Introduction

The purpose of this activity is the introduction of some instruments that will measure the water vapor in the air and the amounts of precipitation.

Materials

hygrometer or dry and wet bulb thermometers
rain gauge
sling psychrometer

Procedure

Obtain as many of these instruments as possible. Do not attempt to explain the principles behind them. Allow the pupils to examine and use the instruments wherever possible. If your good pupils are capable of understanding relative humidity, take the opportunity to explain how relative humidity is calculated.

Emphasize that these instruments extend the senses and aid in measurement.

Extension of this activity

Have the pupils keep a record of the hygrometer readings or dry and wet bulb thermometer readings. Record these data on a chart and include descriptions of corresponding weather conditions, such as fog, rains, clouds, and clear weather.

After these data have accumulated for two to three weeks, have the pupils draw some relationships between the humidity and the corresponding weather conditions.

CONCEPT: Water is an essential part of all living things.

Water is found in all forms of living things; and, because of this, it is important to develop an understanding of some of the many relationships between water and living things.

ACTIVITY 1. Transportation of Water in a Stalk of Celery

Materials

400 milliliter beakers or water glasses
red food coloring
celery

Procedure

Divide the class into four or five groups and provide each group with one stalk of celery, a beaker of water, and food coloring. Instruct each group to examine its celery carefully and to record its findings. Things to observe are condition of celery, color, and length of stalk. After the pupils have made their observations, have them mix the red food coloring into the water and set the stalk of celery in the water.

At this point have the class leave the celery and discuss what they think will be the outcome of this activity. Points that might be discussed are:

1. Do plants need water?
2. How does water get to the tops of plants?
3. What is the sap in trees made of?

After the discussion, have the class go back to the groups and re-examine the celery. (They should observe red streaks running up the stalk and into the leaves.) Have the pupils record their observations and set their celery aside again. Do not let the pupils remove the celery, but leave it in the red-colored water the rest of the day. The redness will increase.

The activity should be culminated with a discussion of why the red-colored water moved up the plant stem. Ask the pupils why red coloring was used in this activity. Does this same movement take place with uncolored water?

ACTIVITY 2. Evidence of What Happens to Water After It Moves Up Through the Plant Stem

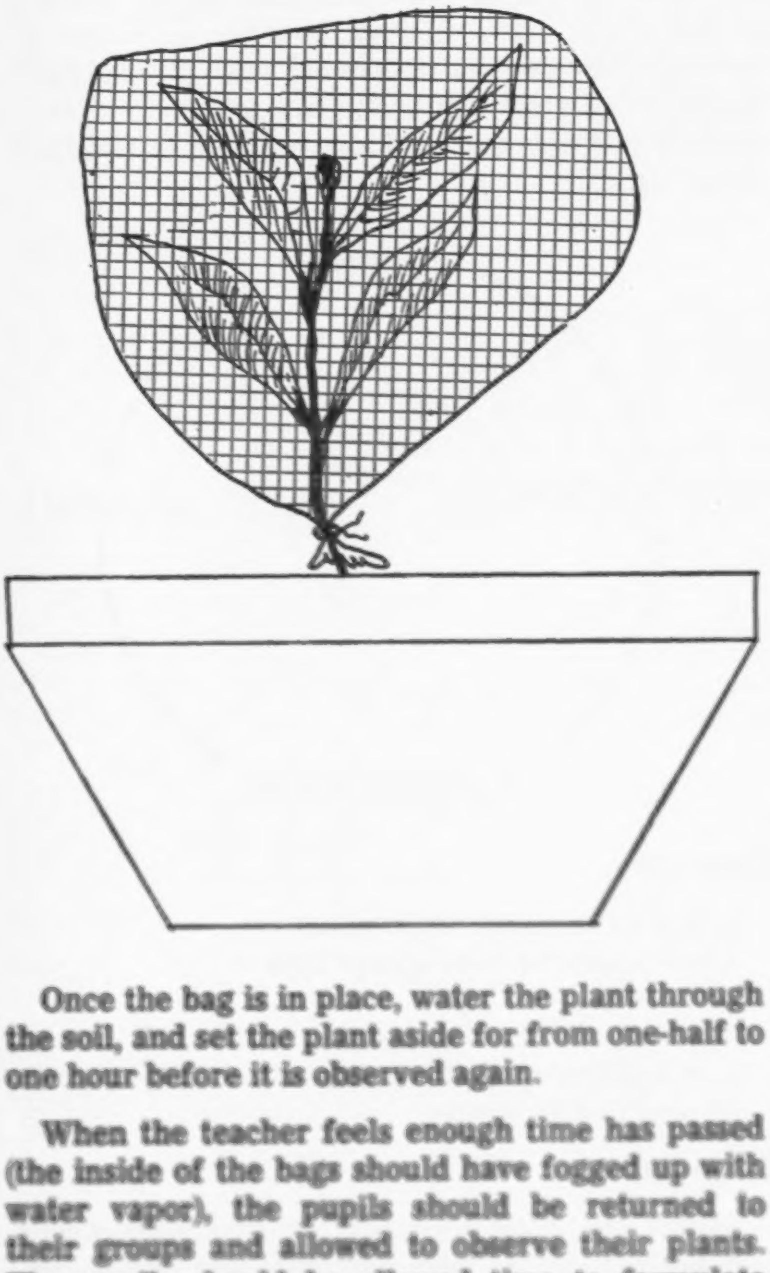
Materials

potted plants
string
plastic bags (large "baggies")

Procedure

Initiate this activity with a discussion of the previous activity. Extend this idea with a question of what happens to the water after it moves up the stem. Have the pupils predict what they think will happen to the water once it has moved up the stem and into the leaves. The teacher should write these predictions on the blackboard.

To begin the activity, divide the class into four or five groups and provide each group with a potted plant, a plastic bag, and a piece of string. Instruct the pupils to put the plastic bag over the entire plant and tie it up snug around the stem of the plant close to the soil.



Once the bag is in place, water the plant through the soil, and set the plant aside for from one-half to one hour before it is observed again.

When the teacher feels enough time has passed (the inside of the bags should have fogged up with water vapor), the pupils should be returned to their groups and allowed to observe their plants. The pupils should be allowed time to formulate theories as to why the bags are foggy and what the fog is. When they have done this, the class should be brought back together and ideas shared.

ACTIVITY 3. The Amount of Water in Living Things

Introduction

This activity can be introduced with a discussion of the amount of water in the human body and expanded to other forms of life. When the discussion has developed to the point where everyone is in agreement that living things have a great deal of water in them, the teacher should hold up a potato and ask if members of the class feel that there is water in the potato. If they do, ask them how they could produce evidence of the water. The class might answer in several ways, such as:

1. Cutting open the potato and seeing the juice.
2. Squeezing juice out of the potato.
3. Cooking the moisture out of the potato.

Materials

potatoes
balance
knives
500 milliliter beakers
hot plate

Procedure

Divide the class into groups and give each group several potatoes, a beaker, a hot plate, and a balance. It might be necessary for all the groups to use the same balance and hot plate.

Have the groups look for direct evidence of water in the potatoes by cutting one and squeezing out some of the juice. After they have completed this, have them weigh one of the potatoes and record the weight. After the potato has been weighed, it should be cut up into as many small pieces as possible. The pieces should then be either baked in a beaker over the hot plate or spread out on a paper towel to dry for several days. If the potatoes are baked, the activity can be completed in one day.

After the potato is thoroughly dried, it should be weighed again and this weight recorded. If the dry weight is subtracted from the wet weight, the resulting difference will be equal to the amount of water lost from the potato.

From this activity, the class should gain an idea of the relationship of water to living things.

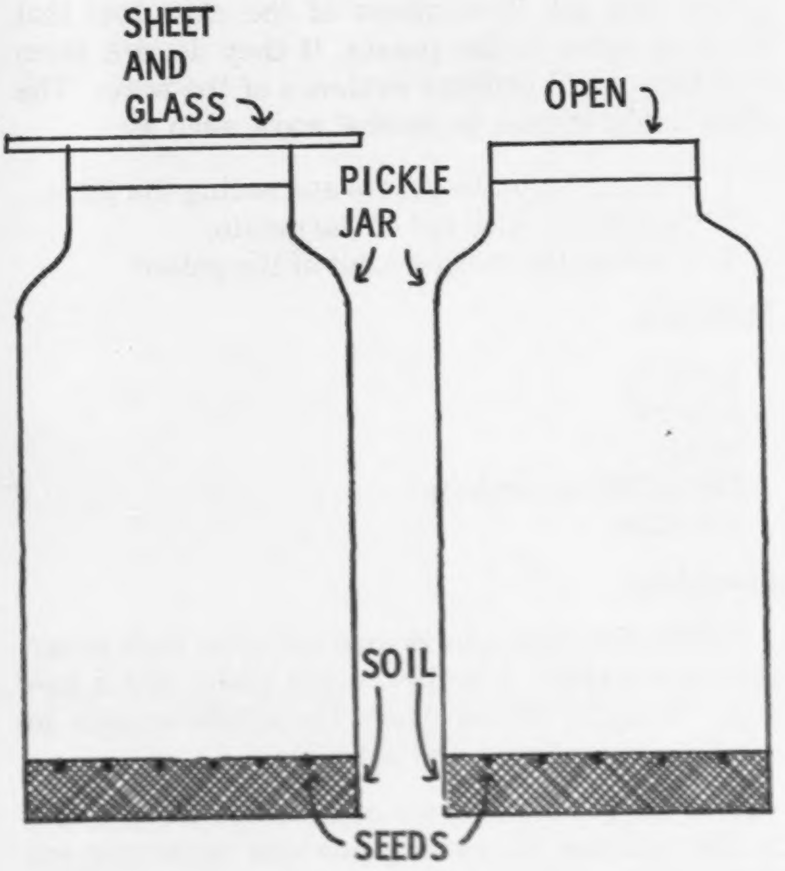
ACTIVITY 4. Water for Growing Plants

Materials

soil
seeds, corn, or beans
1-gallon pickle jars (wide mouth)
sheets of glass, 6 inches square

Procedure

Give each of four or five groups two pickle jars, soil, seeds, and one sheet of glass. Have the pupils place about one inch of soil in each jar. Now have them plant seeds in both jars and add two ounces of water to both. At this point instruct each group



to place a sheet of glass over one of its two jars. These jars should now be set off to one side of the room and observed daily for as long as necessary to confirm the results.

When the results are recorded, the teacher should conduct a class discussion to explain the results.

Points which should be covered are:

1. Why were water droplets on the side of the covered jar and not the other?
2. What happened to the water in the uncovered jar?
3. What happened to the water in the covered jar?
4. Why did the plants grow better in the covered jar?
5. Do plants need water?

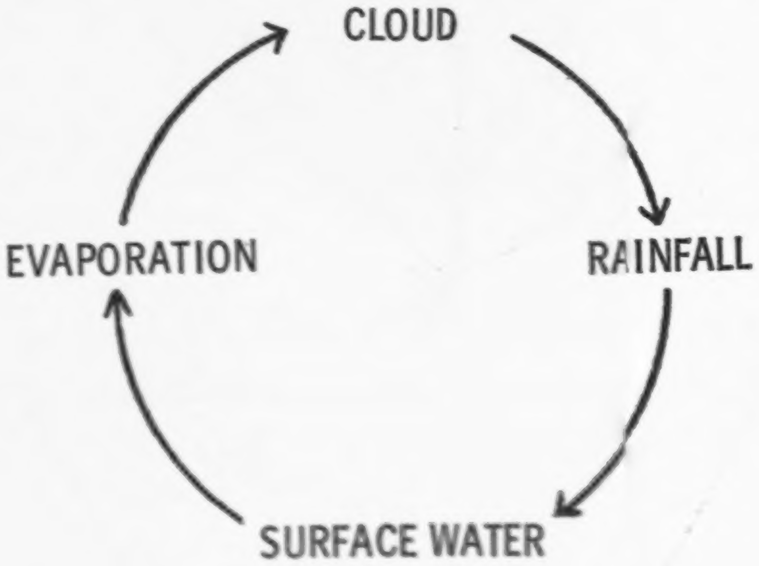
Out of this discussion should come the idea of a closed water system with living things in the system.

CONCEPT: The hydrologic system involves a cyclical change which can be recognized by repeated observations over a period of time.

ACTIVITY 1. Solar Still

Introduction

From this activity the pupils should be able to experience a concrete example of a closed water cycle. It is possible to go from this experience to an understanding of the water cycle on the surface of the earth. It is further possible to draw an analogy between the source of energy necessary to operate the solar still and the source of energy necessary to operate the water cycle on the surface of the earth.



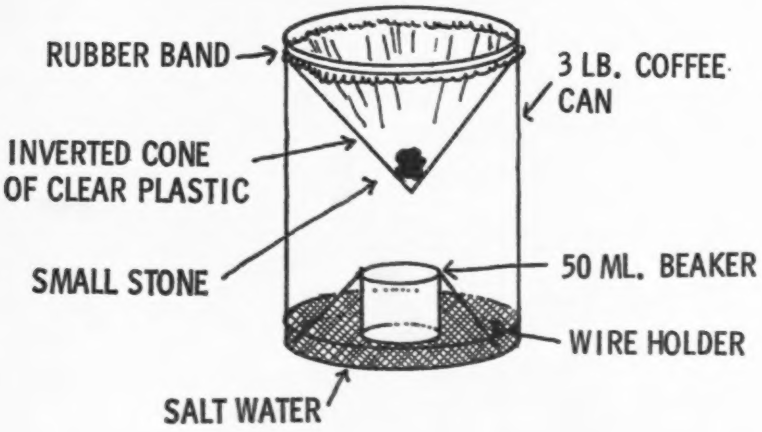
Materials

4 or 5 three-pound coffee cans
4 or 5 sheets of clear plastic film
table salt
4 or 5 50-milliliter beakers
4 or 5 pieces of wire 6" long
several rubber bands

Procedure

Divide the class into four or five goups and provide each group with a three-pound offee can, a sheet of clear plastic, a 50 ml. beakr or small glass, a six-inch piece of wire, and tw or three rubber bands. Instruct the pupils to wire the beaker in such a manner as to suppor it two or three inches off the bottom of the can.After this is completed have the pupils pour eough salt water into the bottom of the can to cover the bottom to a depth of about one inch.

Now with the salt water added and the small beaker in place, the can may be covered with the clear plastic film in such a way it forms an inverted cone with the rubber bands holding the edge of plastic and the point of the cone directly over the small beaker as close to the beaker as possible without touching it. A small stone will hold the point in place.



Now each group should take its completed still outside, set it in the direct sunlight, and observe what happens. After the pupils have had enough time to observe the stills working, they should leave them outside and return to the classroom to discuss how the solar still operates and how its operation relates to rainfall. Some points that should be covered are:

1. What is the source of energy?
2. Did the plastic sheet act as a surface for the water vapor to collect on, as the smoke particles did in the cloud chamber?
3. Will the water in the beaker be fresh or salt water?

After the discussion, the class should go back outside and check the water in the beaker by testing it to confirm any predictions they have made about whether it will be salt or fresh water.

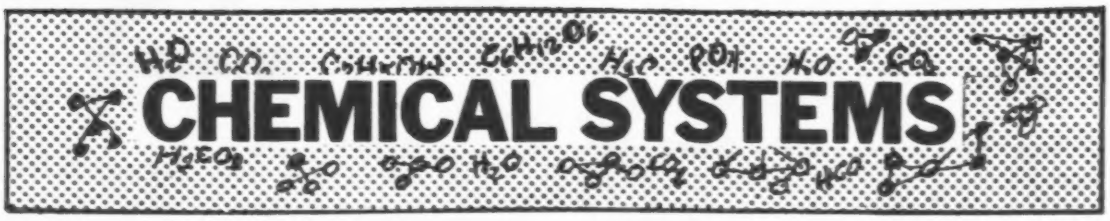
EVALUATION

The major evaluation of this unit might best be accomplished after the completion of each concept development. Stress the utilization of these concepts in their understanding of the earth's hydrologic system. Allow the pupil to use the basic skills of inference and prediction as emphasized in the rationale of the unit.

Suggested evaluation activities:

1. Give the pupil water or ice and have him develop a story concerning the properties of the substance, the relationship of energy to the changing nature of water, and the part water will follow in the water cycle.
2. Observe the local weather during one particular day. Ask the pupil to describe the weather in terms of its relationship to water.
3. Have the pupil determine the amount of water in an apple. Evaluate the procedure used and the pupil's understanding of the importance of water in living things.

GRADE FIVE



CHEMICAL SYSTEMS

THE GREEKS rationalized that if one were to take an object and subdivide it again and again, he would eventually reach a point where subdivision was no longer possible because the ultimate particles had been reached. These particles they called "atome." Although their concept of the atom is not quite the same as our present concept, the concept of a fundamental particle was a valuable contribution to science.

In this unit, an attempt will be made to present to the pupil some evidences presently accepted for the existence of atoms and molecules. The approach in grade 4 was that the pupils were to discover as many ideas for themselves as possible. In this unit, reliance will be made on textbooks to present the concept of atoms and molecules. The laboratory will be used to present certain ramifications of the molecular model of matter.

In this activity the process of *model building* will be emphasized. The nature of a model will be discussed, and the pupils will be asked to formulate a model from indirect evidence.

Another process to receive emphasis is the collection, organization, and interpretation of data. (Reminder: State law requires the use of protective eye devices when handling hot liquids, acids, caustic chemicals, or solids when risk is involved.)

Unit Goals

Upon completion of this unit the pupils should:

1. Know the relationship between molecules and atoms.
2. Understand the nature of a model and see that the molecule is a model of a naturally existing fundamental particle.
3. Be able to use with understanding the terms atom, molecule, element, and compound.
4. Know that atoms and molecules have different properties and that these properties can be used as a basis for identification.
5. Recognize that when chemical change occurs the properties of the substance change.

Unit Development

Chemical systems is a concept which presents to the elementary pupil some of the fundamental ideas in chemistry.

The first concept begins with a library search in which the pupils are asked to find information about atoms and molecules. Do not allow this to deteriorate into oral reports by the pupils. Perhaps a written report would be valuable evidence on which to base evaluation. Certain areas might be selected for emphasis on the basis of pupil interest. The purpose here is to present the atomic theory of matter on a level that fifth grader can understand. Stress the idea that the library is an important tool for the scientist.

This same activity leads nicely to the idea of a model. The emphasis here is placed on the nature of a model, model being defined in terms of the representation of certain properties of an object, but *not* all of those properties.

Activity 3 is really a discussion exercise. The use of the library facilities is again suggested so that the pupils may contribute something to the discussion of elements and compounds. *Do not* expect the pupils to memorize rules or symbols. These should be kept available for the pupils to use. By the time they need to know them the pupils should have used the symbols and rules enough to be familiar with them.

The next concept deals with the different properties which enable one to differentiate between substances. Emphasis is placed on the properties of solubility and dissolubility, chemical reactions, reaction on heating, melting points, and acidic and basic nature of compounds.

The concept of changing properties as a result of chemical change is investigated in two activities which deal with the combination of two elements to form a compound and the decomposition of a compound into its elements.

CONCEPT: Molecules which are made up of atoms are basic particles found in nature.

ACTIVITY 1. Library Search

Introduction

Ask the pupils to use the library and collect as much information about atoms and molecules as possible. The teacher may wish to ask the class to write a short report on the entire area or on some aspect that interests the individuals. Do not ask the pupils to make oral reports, but use the information they glean as a basis for discussion. Emphasize the idea that the library is an important part of a scientific laboratory and a necessary tool to the scientist.

Materials

gumdrops
toothpicks

Procedure

Direct the pupils to use the library and collect as many facts about atoms and molecules as possible. This is a good opportunity to expose fifth graders to the science section of the school library.

When they have collected the facts, use the following outline for points of discussion. Many will have collected information about subatomic particles. Do not go into subatomic particles in this unit. Some information about elements and compounds will also be collected. This will be emphasized later.

1. Atoms are the basic building blocks in nature.
2. There are over 100 different kinds of atoms.
3. Each different kind of atom is called an element.
4. Discuss several different elements and their value to mankind such as:
   Fe - useful as a metal
   O_2 - necessary for respiration
   N - used by plants to make protein
   C - appears in pure form as a diamond
5. A molecule is made up of two or more atoms. When the atoms of a molecule are identical, the molecule is called a molecule of an element. When the atoms of a molecule are different, the molecule is called the molecule of a compound.
6. Some common molecules are:
   a. *oxygen*. The air we breathe is composed of two oxygen atoms.
   b. *water*. The water we drink is made up of two hydrogen atoms and one oxygen atom.
   c. *carbon dioxide*. The carbon dioxide we exhale and that puts "bite" in soda pop is a molecule with one carbon and two oxygens. Note that the atoms in a molecule can be either different or the same.

Inform the class that they are going to make model molecules from gumdrops. Use different colors of gumdrops in a scheme such as the following:

Hydrogen - green
Oxygen - yellow
Carbon - black
Nitrogen - orange

Tell each pupil to make these molecules by breaking toothpicks in half and inserting one end of the toothpick in one gumdrop and one in another gumdrop.

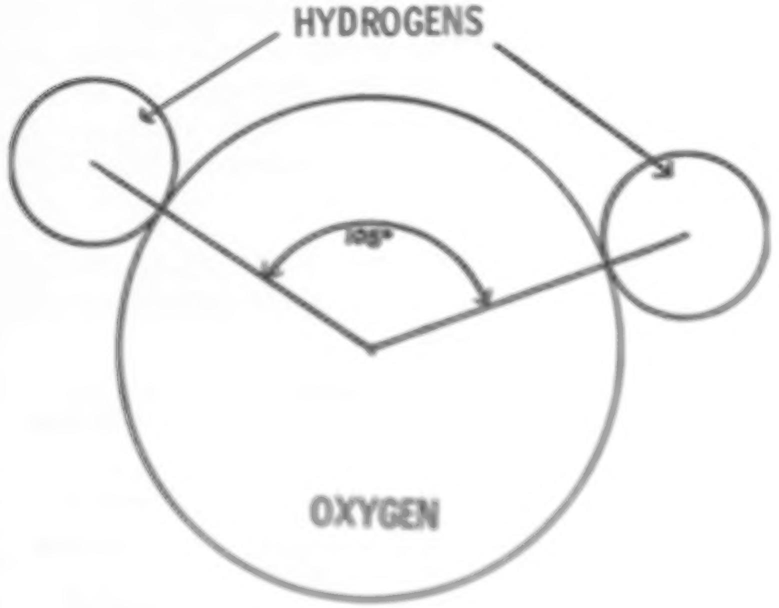
Have everyone make the water molecule first. Do not tell the pupils how to do it, but give them the composition. Water contains two hydrogens and one oxygen. Compare all the different possibilities suggested by the class. These will be (1) H-H-O,

(2) O-H-H or (3) H-O-H. Draw the structures on the chalkboard and ask if they are all different. Using a model, show that (1) could be rotated about the oxygen 180 degrees to give the same molecule as (2). This is a principle to be stressed. If a molecule can be rotated so that it can be superimposed on another molecule, it is the same molecule. This leaves a choice between (1) and (3). Ask which of these should be expected. The pupils will probably not have a basis on which to make their decision. One way to lead them to (3) would be to say that both of the H's have the same properties. If one has the property of reacting with oxygen, the other would be expected to have the same property. Furthermore, a set of rules has developed which works most, but not all of the time. These rules are for molecules with hydrogen, oxygen, carbon, and nitrogen. They indicate the number of bonds that an atom can form when it reacts with another atom to form a molecule.

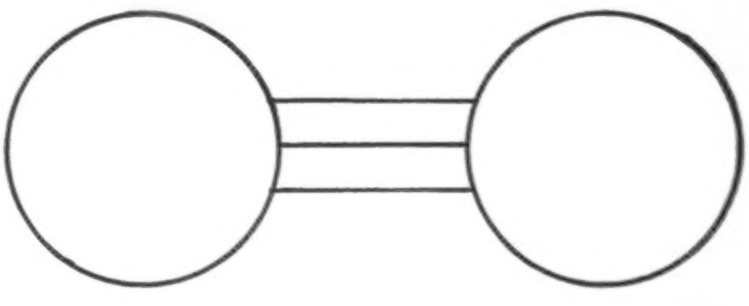
Hydrogen	1 bond
Oxygen	2 bonds
Nitrogen	3 bonds
Carbon	4 bonds

It should be emphasized that these rules will work for all of the cases we will consider, but that they will not work for all cases.

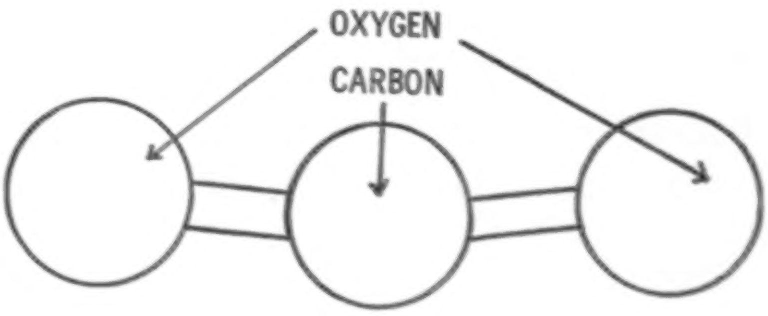
With this knowledge we can eliminate formula (1) for water. Formula (3) is almost correct except that the hydrogens are not opposite each other on the oxygen. They are, in fact, 105° from each other as indicated below:



Have each pupil make the carbon dioxide molecule. Remind them to consider the bonding rules and to use two toothpicks for double bonds, and that the carbon dioxide molecule is composed of two oxygens and one carbon. Explain that the oxygens are opposite each other in carbon dioxide. Their model should look something like this:



Ask: Who can make the nitrogen molecule with two nitrogens? When several are finished, ask how many bonds they used. Their model should look something like this:



When they have completed this work, ask them what they have been doing. Someone will probably say they have been making molecules. Lead them to understand that they have not been making molecules but that they have been making models of molecules. Ask if they can tell why they cannot say they have been making molecules. Lead them to understand that molecules have various properties.

Ask them to name some of the properties that molecules have. Complete a list, which will include the following:

color
odor
chemical properties
size
taste
number of different atoms
kinds of different atoms
arrangement of atoms

Ask what properties we have represented in our models. All of these molecules are colorless, odorless, tasteless; whereas, the models made of colored gumdrops have taste and color. Neither size nor chemical properties have been represented. The models do represent the number and different kinds of atoms and their arrangement in the molecule. Stress the fact that a model is a likeness which presents some, but not all, of the properties of an object. Emphasize that models represent *some* aspects of the real object. Ask if the pupils know about any models of other objects. If there is no response, remind them of model cars, manikins, and doll houses.

ACTIVITY 2. *More on the Black Box*

Introduction

In the previous activity the problem of model building was brought up. In the fourth grade unit, "Measuring Systems," this experiment was done but the emphasis was on observation vs. interpretation. Here a similar format will be used, but the emphasis will be on model building. It is suggested that four groups be used.

Materials (per group)

1 cigar box
1 fresh egg
masking tape

Procedure

Place a fresh egg in a cigar box and seal each edge with masking tape. Direct each group to examine the box, making observations about its contents. Ask one pupil from each group to record the group's observations at the chalkboard.

If the pupils do not shake the box hard enough to break the egg, tell them to shake it vigorously after all have had a chance to tilt it. Have them take the lists of observations. Arrive at a model for the object inside the box. Caution them not to say what object they think is in the box. Do not reveal the contents of the box.

A balloon filled with water is an alternative to the egg, but it is harder to break, and the water is more difficult to keep in the box.

The class should be led to conclusions about the shape and strength of the object. Ask if anyone can relate this to atoms and molecules. Tell the pupils that just as they could not see the egg in the box, neither can a scientist see the atoms and molecules with which he works. He must do something to the atom and infer its structure from the result.

ACTIVITY 3. *The Place of Elements and Compounds*

Introduction

In previous activities the concept of atoms and molecules was examined via library search plus two activities which dealt with model building. However, the pupil does not see atoms or molecules around him. What he does see in plants, machines, animals, and minerals could be broken down into elements and compounds. The purpose of this activity is to lead the pupil to understand that elements and compounds are accumulations of large numbers of atoms and molecules.

Materials

None

Procedure

Take the pupils to the library and ask them to find and record information about elements and compounds from science books, encyclopedias, and textbooks. When they have finished, lead a discussion using the following outline:

1. Review the fact that an atom is a small basic particle with certain properties which identify as one of the elements.
2. Review the relationship of atoms to molecules. Molecules are the particles we find in nature. Atoms, with a few exceptions, are not found in nature because they tend to react to form molecules.
3. Molecules are generally composed of two or more atoms. If the atoms are different, the molecule is called the molecule of a compound. When the atoms are the same, the molecule is called the molecule of an element. Point out that the inert gases are an exception in that their molecules have only one atom each.

Give the class the following list of substances and ask the pupils to determine if the substances are compounds or elements:

Substance	Atomic composition	Answer
water	2 hydrogens, 1 oxygen	compound
iodine	2 iodines	element
oxygen	2 oxygens	element
carbon dioxide	1 carbon, 2 oxygens	compound
baking soda	1 sodium, 1 hydrogen, 1 carbon, 3 oxygens	compound
chlorine	2 chlorines	element
iron	iron atoms	element

4. The chemist has a set of symbols he uses in place of the entire name for an element. Place

the following list of names and symbols in a prominent place in the room so that all pupils may see and read it from their seats. *Do not* ask them to memorize these symbols:

Element	Symbol	Element	Symbol
Aluminum	Al	Iodine	I
Argon	Ar	Iron	Fe
Barium	Ba	Magnesium	Mg
Berllyium	Be	Manganese	Mn
Boron	B	Mercury	Hg
Bromine	Br	Neon	Ne
Calcium	Ca	Nickel	Ni
Carbon	C	Nitrogen	N
Chlorine	Cl	Oxygen	O
Chromium	Cr	Phosphorous	P
Cobalt	Co	Potassium	K
Copper	Cu	Silver	Ag
Fluorine	F	Sodium	Na
Gold	Au	Sulfur	S
Helium	He	Tin	Sn
Hydrogen	H	Uranium	U
		Zinc	Zn

Point out that the first letter of each symbol is always capitalized, and that the second letter, if there is one, is always small.

5. Compounds can be written using these symbols and the rules for the number of bonds that were presented in Activity 1. The teacher may wish to review these rules at this time.

In writing formulas, the symbol for an element always stands for one atom of that element unless there is a subscript. For example, H_2O is composed of two hydrogens and one oxygen. The subscript 2 means there are two hydrogens. Oxygen is written with no subscript and indicates one oxygen. Have the pupils give the kind of atoms and the number of atoms for each of the following compounds:

Compounds	Answer
H_2CO_3	2 hydrogens, 1 carbon, 3 oxygens
$NaOH$	1 sodium, 1 oxygen, 1 hydrogen
H_2SO_4	2 hydrogens, 1 sulfur, 4 oxygens
$CuSO_4$	1 copper, 1 sulfur, 4 oxygens
KNO_3	1 potassium, 1 nitrogen, 3 oxygens
$MgCl_2$	1 magnesium, 2 chlorines
$CrCl_3$	1 chromium, 3 chlorines
Ag_2O	2 silvers, 1 oxygen
$ZnBr_2$	1 zinc, 2 bromines

CONCEPT: Different substances possess properties which enable one to identify them.

ACTIVITY 1. Differentiating Between Baking Soda and Powdered Sugar

Introduction

In this activity stress is placed upon the different properties of different substances. The pupils should begin to develop ideas about the kinds of properties which enable one to differentiate between substances.

Materials

powdered sugar
baking soda (sodium bicarbonate)
vinegar
2-100 ml. pyrex beakers or glass tumblers

Procedure

Divide the class into groups and give each group a tablespoon of powdered sugar and baking soda. Have the class record the following observation. Discuss how these two substances look very much alike; they also feel alike. Ask how you can distinguish between them. Someone may suggest tasting them.

CAUTION: Generally speaking, it is a very bad practice to allow pupils to taste chemicals in the classroom. Baking soda and sugar are "chemicals." They happen to be safe for tasting as long as they are pure. The teacher should stress the fact that in the science laboratory the pupils should not put materials in their mouths for tasting. However, if tasted, these two substances (baking soda and sugar) would give different tastes.

Pour household vinegar into two beakers and put the soda in one container and the powdered sugar in the other. Observe the differences. The soda will give off bubbles of carbon dioxide.

Place the small sample of the sugar in a pyrex test tube and heat to a very high temperature over a bunsen burner. The sugar will darken and form charcoal. Place a small sample of the baking soda in a similar test tube and heat it in the same manner. The baking soda will not undergo any apparent change. Note the differences in appearance.

Finally, direct each group to add a tablespoon of sugar to 100 ml. water and stir. Ask them to follow the same procedure for baking soda. Let this mixture stand for several minutes. Have each group record the results. Discuss the different bases on which these two compounds could be differentiated.

ACTIVITY 2. Melting Point as a Differentiating Property for Substances

Introduction

Another property used to differentiate between substances is their melting temperature. Emphasize through this activity that all substances melt and that there is a wide variety in the melting temperatures.

Materials

250 ml. beaker
paraffin wax (m.p. about 38° C)
paradichlorobenzene (m.p. about 51° C)
burner
2 large pyrex test tubes
centigrade thermometer
utility clamp
tiny stand

Procedure

Have the pupils examine paraffin wax and paradichlorobenzene for their apparent properties. Point out that they appear similar in color, but they are different in the way they smell and feel, and in hardness. Direct each group to place enough chips of paradichlorobenzene in a test tube and melt. Allow the liquid to cool and solidify. Insert the test tube into a beaker half full of water. Lower the test tube into the water until the level of the water is just above the level of the paradichlorobenzene. Direct the pupils to heat the water gently and slowly, carefully watching the thermometer in the test tube. When the test tube is about half liquid and half solid, ask them to check the temperature. This same procedure should be repeated for the paraffin.

Paradichlorobenzene will be sublime (solid changing to a gas without an intermediate liquid base). At room temperature, and if left open, it would completely sublime. The tubes can be maintained in a coffee can until next year.

When the class has finished, discuss their results. Ask what they think the melting point of iron would be. The temperature of this is very high, about 1,535° C. Point out that even if these substances could not be distinguished on the basis of some other property, they could be differentiated on the basis of their melting points.

ACTIVITY 3. Differences in Ability to Dissolve

Introduction

In a previous activity the idea of the differences in the ability of a liquid to dissolve other substances was considered. This activity attempts to present the idea that a solid substance dissolves in different liquids to different extents.

Material

4-500 ml. identical florence flasks
4 corks to fit the above flasks
400 ml. of glycerine
400 ml. of distilled water
400 ml. of rubbing alcohol (70% isopropyl)
400 ml. of household ammonia
salt (sodium chloride, NaCl)
4 tablespoons
4 meter sticks or metric rulers

Procedure

Divide the class into four groups. Give each group a flask, cork, salt, tablespoon, and one of the liquids. All of the liquids should be at room temperature. Direct each group to carefully measure one level tablespoon of salt and place it in the flask with the liquid assigned the group. Stopper the flasks and swirl so as to mix the solid and liquid. If the solid does not dissolve, repeat the swirling motion. After several swirls, have each group check to see if the salt has dissolved.

Each group should repeat the procedure, keeping careful record of the material added until some solid is left in the flask, i.e., until some solid is left undissolved. As the groups reach this point, they should stop until all groups have some solid left. Then ask which group had to add the most. Ask how much they used.

This would be a good place to stop and let the flask stand overnight. Direct the other three groups to subtract the amount added by the group reporting the largest amount added; add that to their liquid. Then direct all groups to swirl their flasks and invert them, being careful to secure the cork. Direct the groups to measure the amount of solid left with a meter stick by measuring from the cork to the top of the solid. Record the results of their work on the chalkboard and discuss the results in terms of the ability of different substances to dissolve.

Remind the pupils that each group added the same amount of solid. The group which worked with glycerin may wish to ask why the salt settled so slowly in glycerine. The teacher will wish to discuss the greater viscosity of glycerine if this is mentioned.

ACTIVITY 4. Acids and Bases

Introduction

Acids and bases have certain chemical properties in common. In this activity acids and bases common to the home will be used. The teacher may be aware that one of the most common ways to define acids and bases is in terms of ionizable hydrogen and hydroxide ions. That point will be avoided in this activity because all of the acids and bases used do not have ionizable hydrogen or hydroxide ions. Definition of acids and bases will be in terms of their reaction with litmus.

Materials

- blue litmus paper
- pink litmus paper (sometimes called red litmus)
- orange, lemon, grapefruit
- vinegar
- household ammonia (3% ammonia)
- borax
- washing soda
- distilled water
- medium droppers
- 3-100 ml. pyrex beakers
- tea
- fresh red cabbage

Procedure

Instruct each pupil to prepare the following table:

Substance	Blue litmus	Red litmus
lemon juice		
ammonia		
orange		
borax solution		
vinegar		
washing soda solution		

Tell the class that certain compounds react to change the color of blue litmus. Other compounds react to change the color of pink litmus. Give each pupil a piece of litmus and have him check the reaction of litmus paper and distilled water. Tell the pupils that litmus does not react with distilled water and that what they observe is the wetting of the paper by the water. Ask them to wet several small pieces of litmus paper with distilled water and test each of the substances with both red and blue litmus. A solution of washing soda and borax can be made by mixing with water.

Place the chart on the chalkboard and fill in pupil responses. **CAUTION:** Household ammonia should be used in a ventilated room. Keeping the lid on the container will keep the fumes down. Instruct the pupils to wash their hands if they get ammonia on them.

It should be evident to the class that those compounds which react with blue litmus do not react with red litmus. Furthermore, the compounds which reacted with red litmus did not react with blue litmus. Finally, it should be evident that the only color changes were blue to red and red to blue. If the above is not suggested by the pupils, lead them to these conclusions.

Ask what would happen if blue litmus were placed in vinegar and then placed in ammonia. Ask the class to try it and see. They will report that blue litmus turns red in vinegar and back to blue in the ammonia. Ask what they can conclude about red and blue litmus paper. Litmus is a substance which is red in acids and blue in bases.

Blue litmus paper is made by dipping litmus-soaked paper into a base; then the paper is dried. Ask how red litmus paper would be made. Pink litmus paper is made just as blue litmus paper except that it is dipped into acid before being dried. Lead the class to conclude that litmus is red in acids and blue in bases. Tell them that litmus is called an "indicator." It gets this name because of its reaction with acids and bases.

There are many indicators. One that is common in homes is tea. Prepare tea as directed on the package and cool to room temperature. Give each group two 100 ml. beakers. Direct the group to mark one for a control and add 50 ml. of tea to each. Add a few drops of vinegar to the experimental beaker. Compare with the control. Then add a few drops of ammonia to the same beaker and record observation.

A similar experiment can be done with red cabbage. The cabbage should be boiled until the water is dark red. Follow the same procedure as used above with tea.

Lead a discussion enumerating all the properties which might be used to tell the difference between substances.

CONCEPT: When substances undergo chemical reactions their properties change.

ACTIVITY 1. Elements React To Form Compounds

Introduction

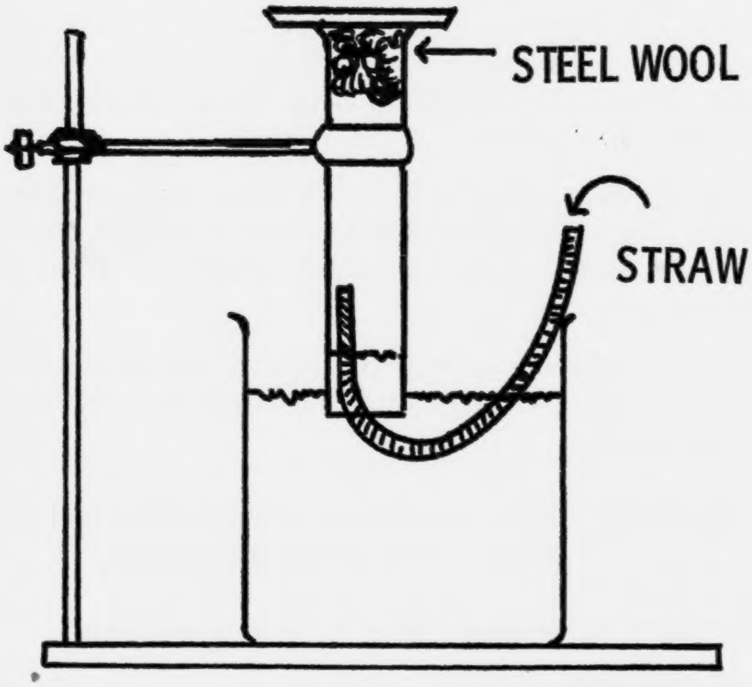
In this activity the emphasis is on how properties change when chemical change occurs. In keeping with activities of the previous concepts it will be well to use chemical symbols and encourage the pupils to do so wherever possible. Keep the list of chemical elements and symbols before them at all times.

Materials

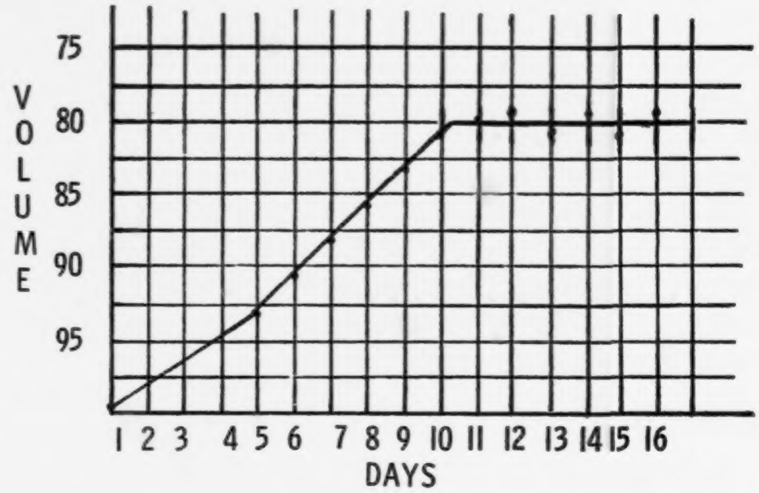
- steel wool
- 5-100 ml. graduated cylinders
- 5 ring stands
- 5 utility clamps
- 5-500 ml. pyrex beakers
- wood splints
- rubber tubing

Procedure

Be sure to use steel wool and not soap pads. It will be necessary to clean the steel wool by dipping it in vinegar until bubbles form and then rinsing thoroughly with distilled water. After cleaning, shake the water out and place it loosely in the bottom of a 100 ml. graduate cylinder. Use enough to loosely pack the cylinder about one-fourth full. Invert the graduate and submerge the open end below the surface of the water in a 500 ml. beaker nearly full of water. Direct each group to insert the graduate in such a way that the water level inside is up to one of the markings at the open end of the graduate. This can be done by putting the graduate into the water at an angle. An alternative would be to use a rubber tubing or a bendable straw to move air by sucking as illustrated below.



The graduate can be suspended in a utility clamp which is attached to a ring stand. When the setups have been completed, direct the pupils to make a chart, such as the following:



Date	Reading
Sept. 3	99
Sept. 4	none
Sept. 5	none
Sept. 6	93
etc.	etc.

Direct the class to make recordings every day, writing down the dates in order and recording the readings on that day. On days when no readings are taken, remind them to write none on the chart. At the same time ask them to begin plotting points on the graph as shown. Use time on the horizontal line. Use the vertical line for the volume readings, starting with 100 and going up. A plot of their data will rise, then level off, as shown. Because of barometric pressure and temperature changes, the points will not all fall on a line. But when they level out generally, all the oxygen should be reacted, and the experiment should then be terminated. This may require two weeks.

Do not tell the pupils how to interpret the graph. See if they can. The best readings will be taken when the level of the water inside the graduate equals the level outside. Under these conditions the internal pressure will equal the external pressure. Remind the class that when they plot the graph, the days for which there are no data should be left blank, i.e. if there were no data taken on the second and third day, these should be skipped and data for the fourth day plotted over four on the horizontal axis.

When the reaction is complete, ask the class to record what they observed. The iron will have rusted and the air will have changed volume. Ask how the iron has changed. Flaky orange rust will be apparent. Ask how the air has changed. They may suggest the volume will have been reduced. Ask if it is different in any other way. Ask why its volume is reduced. Someone may suggest that something has been removed. Ask if anyone knows what the air is made of. Tell the class that the air is made up mainly of oxygen and nitrogen, with a few other gases.

Inform the pupils that if the properties of oxygen and nitrogen were known then one might test to determine which, if either, is present. Ask if anyone knows a property of oxygen. If no response, tell them that oxygen helps things burn. In fact, oxygen is necessary for the burning of almost everything. Light a candle and put a glass container over it to demonstrate this fact. Ask how this might help to determine contents of the graduate.

After a discussion, take one of the graduates out of the water and quickly cover it with a piece of plastic and a rubber band. Light a wood splint and remove the plastic and quickly insert the splint and note how quickly it goes out. Take a similar graduate full of air and thrust a burning splint into it, noting that the splint burns. Explain that this is evidence that the oxygen has been removed from the graduate. What is left? They should conclude that nitrogen is left.

Tell them that oxygen is an element with two atoms per molecule. It is written O_2. Tell them that the element iron is written as a single atom, Fe. Write on the chalkboard:

O_2 + Fe gives rust

This is a chemical reaction. The elements oxygen and iron both change their properties as they react to form the compounds in rust. Tell them that most metals react with oxygen from the air to form compounds. Iron forms two compounds when it rusts, FeO and Fe_2O_3. This is an example of one element reacting with another element to form a compound.

The next activity will deal with a chemical reaction which involves the breakdown of a compound into its elements. These are two basic kinds of chemical reactions.

ACTIVITY 2. A Compound Reacts To Form Elements

Introduction

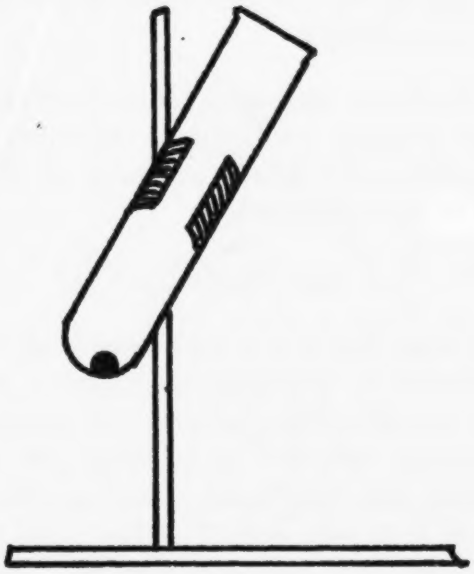
The purpose of this activity, as indicated in Activity 4, is to show that a chemical change occurs when a compound breaks down into its elements.

Materials

bunsen or propane burner
mercuric oxide (mercury II oxide, HgO)
2 pyrex test tubes
utility clamp and ring stand

Procedure

Demonstrate the following for the class. Work near the center of the room so that all pupils can see. Place a small amount of HgO in a test tube. Pass this tube around for the pupils to observe while you set up the following experiment:



Place a small amount (about one-half teaspoon) of the mercuric oxide in a test tube and fasten it to a ring stand as indicated above. Heat the test tube vigorously. After a time, the compound will begin to disappear in the bottom of the tube. The mercury will condense on the sides of the tube near the open end, probably under the clamp first. This is called the "silver mirror" because it looks like a mirror.

When the mirror forms, allow the pupils a close look, but do not allow them to touch the mercury. Ask if they can explain it. Tell them that HgO is the formula for the compound. Ask them which elements are present and how many atoms of each element are involved. Ask what the material is that makes up the mirror. Suggest that it has metallic properties and lead the pupils to conclude that the metal mercury is the material causing the mirror.

Ask what happened to the oxygen. They may suggest it is still in the tube. It may still be there, depending on the amount of time since it was heated. Ask if anyone can suggest how to test for oxygen. Ask what they know about oxygen. If they have already completed Activity 1, they may suggest that it helps substances burn.

Tell the class that substances burn faster in pure oxygen. Air is part nitrogen. If a slowly burning object is thrust into pure oxygen it will burn faster, producing a flame.

At this point, add a similar amount of HgO to another test tube and repeat the heating process. When the mirror is visible, light a wood splint. Shake it "out" in the air so that no flame remains but some glowing is observed. Put the glowing splint quickly to the test tube. It should burst into flame immediately.

Remind the class that the demonstration was done by heating a compound. HgO reacted to form the two elements which compose it. Write the following on the chalkboard:

$$HgO \text{ gives } O_2 + Hg$$

Note that there are two atoms on the left and three atoms on the right side. Ask if it is possible for one oxygen atom to form two oxygen atoms. If no response, ask if it is possible for one baseball to become two baseballs. They probably will suggest that it is not. Ask if anyone can suggest how to start writing HgO and get O_2. Write on the board:

$$2HgO \text{ gives } O_2 + ?Hg$$

How many Hg's are produced? Hopefully, the class will suggest two. Tell them that this is a chemical equation. The word "gives" is usually replaced with an arrow (⟶). When the number of atoms on the right is equal to the number of atoms on the left an equation is said to be balanced. CAUTION: Do not allow the mercury to remain exposed in the classroom. Put the tubes in a paper towel and dispose of them.

ACTIVITY 3. An Element Replaces Another Element in a Compound

Introduction

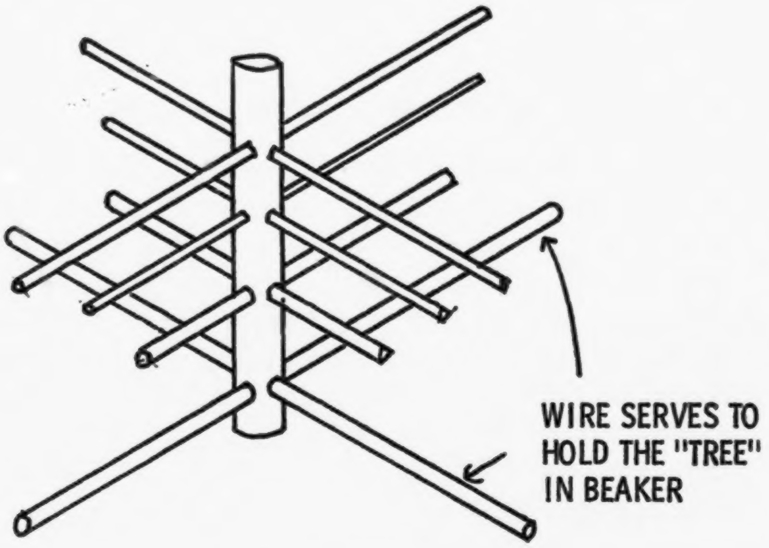
There are many reactions which fall into the category of replacement reactions. The reaction of lead acetate and zinc metal is only one example. This activity will be done as a demonstration, but pupils should be asked to help assemble the apparatus and make the solution.

Materials

3/8" x 6" wooden dowel (from lumber yard)
lead acetate $Pb(CH_3COO)_2 \cdot 3H_2O$
large round glass battery jar or 1,000 ml. beaker
zinc strips

Procedure

Take the wooden dowel and drill two holes at right angles through the base about 1/4" from one end. Then, drill 1/8" holes 1/2" to 3/4" apart and insert the zinc strips, arranged as though they were the branches on a tree as illustrated below.



Invert this in a battery jar and adjust the wires so that the "tree" comes to within an inch of the bottom of the jar.

Prepare a 5% lead acetate solution. A 1,000 ml. beaker would require about 900 ml. of solution. Weigh out about 45 grams of lead acetate and dissolve this in 855 ml. of distilled water.

Remove the "tree" from the beaker and add the solution. Then put the "tree" back in place and let stand. Don't let the wires touch the solution. Direct the pupils to observe what is happening.

Small lead crystals will form and the "tree" will begin to look more tree-like.

Ask the pupils what is happening. Give them the formulas for the two substances.

$$Zn \text{ and } Pb(CH_3COO)_2$$

Lead the class to the conclusion that the element zinc replaces the lead in the compound lead acetate, giving lead metal (the metal crystals they observe) and zinc acetate, which is dissolved in the solution. Emphasize that this is an example of one element replacing another element in a compound. This is another basic type of chemical change.

EVALUATION

The evaluation should be made in terms of the unit goals presented at the beginning of this unit. Careful attention should be given to avoid the asking of questions for which the answers are essentially factual recall.

An ideal way to evaluate the pupils is to present them with a situation similar to those presented in the activities. These situations should appear similar but insofar as possible they should be situations which the pupils have not faced before. Some examples are given below, but the teacher should develop some of his own.

1. Ask the class to sketch and label models of the following substances. Tell them that Cl forms one bond.
   nitrogen + 3 hydrogens to give ammonia
   hydrogen + chlorine to give hydrogen chloride
   carbon + chlorine to give carbon tetrachloride
2. Two substances are similar in appearance. What properties might be used to distinguish between them?
3. A certain substance is dissolved in water and found to turn pink litmus blue. Is it an acid or a base?
4. A liquid is tested with blue litmus and no reaction occurs. What are two possible explanations for this?
5. Give the kind and number of elements in the following compounds:
   C_6H_6
   $NaHCO_3$
   $CuSO_4$
   Hg_2Cl_2
   KO
   P_2O_5
6. A substance is known to have the formula P_4. Is it a compound or an element? What about CO?

FORCE SYSTEMS

FORCES ARE BASIC to the understanding of the pupil's environment. Forces are classified into various kinds and are measurable. Force systems are utilized to develop the basic skills of hypothesis formulation, interpretation of data, and model building.

Hopefully, pupils will develop models of the forces and force fields acting on and in their environment. Model building, therefore, becomes a primary skill.

Proper concern is developed for the conpilation of data in terms of forces; however, the emphasis is now placed on the interpretation of data. Stress the importance of fitting interpretations to the data.

A hypothesis serves to explain phenomena. The force system will lend itself to the development of this complex skill.

Unit Goals

Upon completion of this unit the pupil should be able to:

1. Analyze a complex machine in terms of its simple component machines.
2. Understand that forces are the cause of changes in motion.
3. Identify forces and force fields as primary elements in our environment.
4. Understand the relationship between the forces of electricity and magnetism.
5. Describe the force field between magnetic poles.

Unit Development

This unit will deal with three force systems: mechanical force systems, gravitational force systems, and magnetic force systems. There are many other force systems not mentioned in this unit such as electrical force systems. These have been left out because the three mentioned give a good overview of force systems and their interactions, and seem to lend themselves to this grade level.

CONCEPT: No matter how complex a machine appears to be, it can be explained in terms of three simple machines: the wheel, the lever, and the inclined plane. Many variations of these three simple machines exist. For example, a gear is a toothed wheel, and a screw is just a coiled inclined plane. It is therefore important that pupils gain a full knowledge of and a feeling for these simple machines. This knowledge and feeling can best be brought about by activities where pupils can handle and manipulate the various forms of machines. Once this insight has been gained, more complex machines, e.g., a watch, can be evaluated in terms of their components.

ACTIVITY 1. The Lever

Introduction

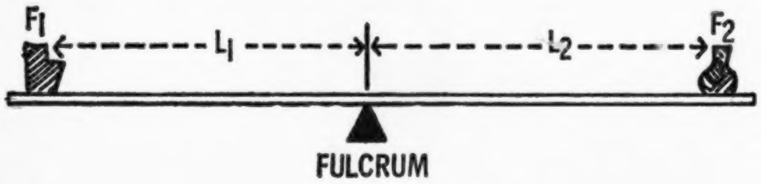
In this activity the lever will be examined and certain of its properties pointed out. If it is possible the teacher should provide a variety of experiences with levers of several different kinds.

Materials

meter sticks
string
weights
spring scales

Note: If your classroom does not have a set of weights, a set can be made with baby food jars filled with sand and weighed on kitchen scales.

Procedure



Draw the above diagram on the board and ask pupils to set up a lever of their own with a real meter stick and weights. Now call attention to the mathematical relationship F_1 x L_1 $\cdot F_2$ x L_2. Once the relationship is understood pupils should be encouraged to vary F and L and note the relationship. (Does it comply with what has been stated?)

After this lever has been thoroughly investigated, have the class discuss the different types of levers that they are familiar with such as:

1. A see-saw
2. A pry bar
3. A wrench
4. A baseball bat

After some examples have been mentioned and recorded on the blackboard, have class members identify the fulcrum on each lever.

Culminate this activity with a trip to the playground, where class members may experiment with the see-saw.

ACTIVITY 2. The Wheel

Introduction

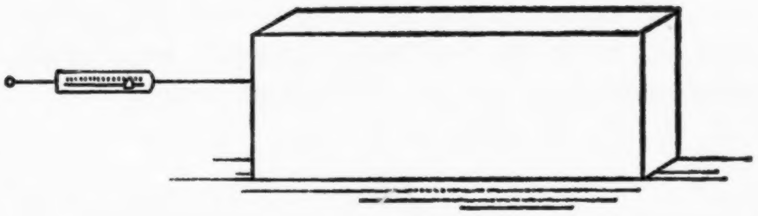
The wheel is one of the most basic inventions for all of modern industry. Gears, pulleys, and rollers are all special adaptations of the wheel. The wheel allows heavy objects to be moved from place to place with much less effort because it reduces friction.

Materials

small spring scales
an assortment of pulleys
wheels
string
small buckets (about 2 qts.)
rollers
weights
boxes

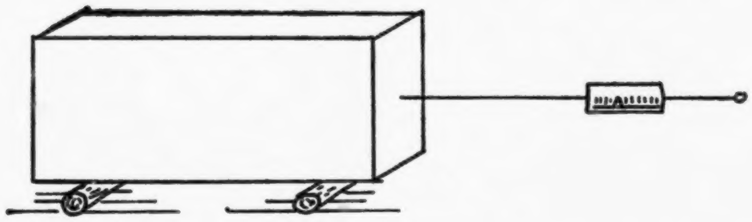
Procedure

For this exercise, divide the class into as many groups as the equipment will allow. Provide each group with a cardboard box (about 18" x 20" in size), some weights (books will work nicely), a spring scale, and two rollers. Have each group put some weight in the box and try to pull it across the floor by a rope to which the scales are attached.



While pulling the weighted box at a steady rate, have the pupils make a reading of the scales and record the data.

Now have the pupils repeat the activity with everything the same except with rollers under the box.



Again have them measure the pull on the scales and record the data. The pupils should now discuss the reasons for the difference in the two recorded readings of the scale. This can be followed by a class discussion. Some points that could be discussed are:

1. Why will a coaster wagon go easier than a sled on dry pavement?
2. How does a wheel compare to the rollers used in this activity?
3. How do you think the first wheel was invented?

ACTIVITY 3. The Pulley

Introduction

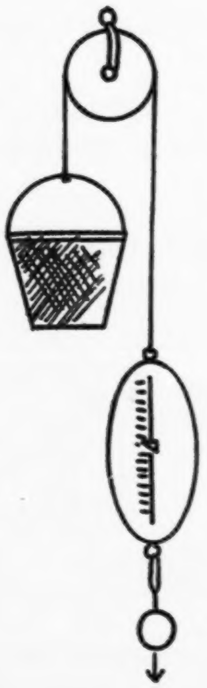
The pulley is a wheel which allows the direction of pull without reducing the force of the pull.

Materials

- pulleys
- rope
- small pails
- sand
- spring scales

Procedure

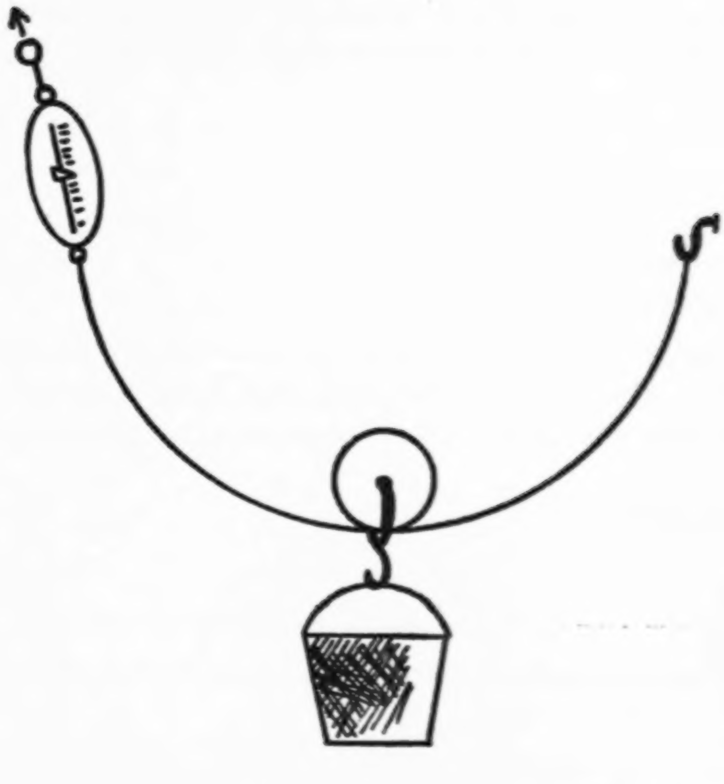
Divide the class into as many groups as your equipment will allow. Provide each group with a pulley, a pail, some rope, and sand. Instruct them to weigh out two or more pounds of sand into their pails and record the weight. Now, with the pulley arranged as in the following diagram, have them measure the pull on the string and record it.



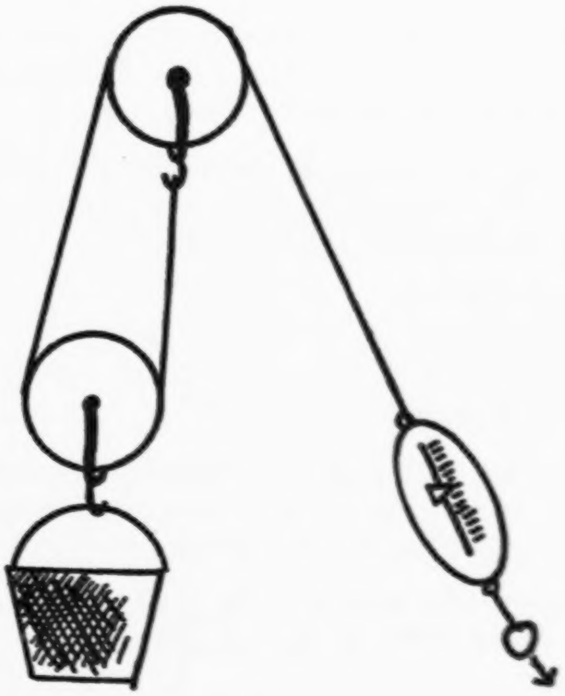
They should compare the two measurements and explain why they are alike. (If there is a small difference it could be due to the friction of the pulley and should be disregarded.)

Next have them measure the pull on the rope when the rope and pulley are arranged as in the following diagram. They should record this weight, too.

Now they should compare their measurements and try to explain why they are alike.



Now with their pulleys have them set up an arrangement like that in the following diagram.



With this arrangement have the pupils measure the amount of pull it takes to lift the pail and compare this figure to the weight of the pail. Also have pupils measure the distance they must pull the rope to cause the pail to move one foot. Can they see a relationship?

This activity should be finished with a discussion of the pulley and how it is used in complex machines such as derricks and cranes.

ACTIVITY 4. The Inclined Plane

Introduction

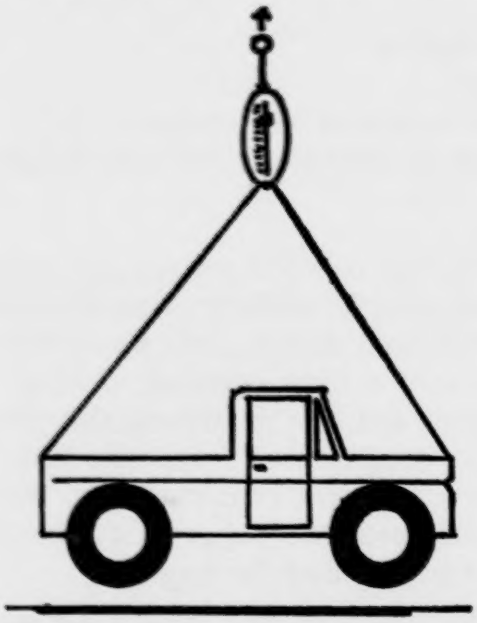
The third and last type of simple machine is the inclined plane. The simplest type of inclined plane is a wedge, but if you twist an inclined plane you have a screw.

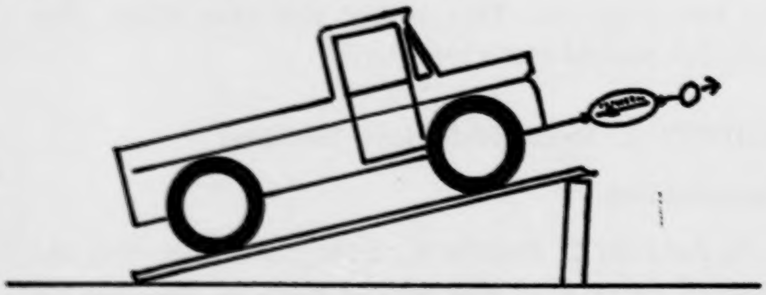
Materials

boards 3 or 4 feet long and 6 inches wide
trucks, small toy trucks
spring scales
blocks or weights

Procedure

With the class divided into groups and each group provided with a toy truck, weight, scales, and a board to use as a ramp, instruct each group to load its truck with blocks or weights and weigh it. Once they have weighed the trucks with their weights, have them record the results. Now with the board, have the pupils construct a ramp and pull the truck up the ramp by means of a scale hooked to the front of the truck.





Now have the pupils record the force necessary to pull the truck up the ramp.

This activity should be repeated over several times with each group using a different angle on the ramp each time. After they have recorded several measurements, ask them to discuss the principle involved. They should be able to state in their own words that the steeper the ramp the more force will be necessary to move the truck, but that the steeper the angle of the ramp the shorter distance the truck has to be pulled to reach a given height.

Finish this activity with a class discussion which will allow members to share their views. Also in this discussion some questions that should be covered are:

1. How is a screw an inclined plane?
2. How are spiral stairways a form of inclined plane?
3. What are some of the ways in which we make inclined planes work for us?

ACTIVITY 5. The Complex Machine

Introduction

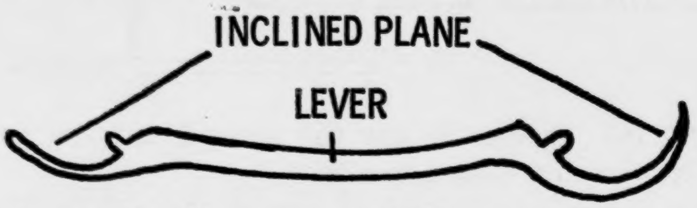
The last four activities have dealt with the three simple machines, the wheel, the lever, and the inclined plane. In this activity an attempt will be made to show how simple machines are caused to function together to form a complex machine.

Materials

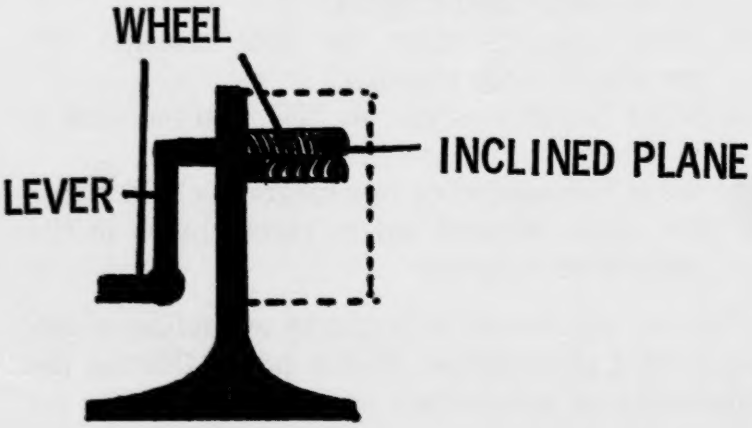
None

Procedure

This activity can best be conducted as a class discussion where complex machines are shown to the class in pictures which pupils have brought in. For example, the picture of a can opener can be explained as a lever and an inclined plane.



A pencil sharpener could be explained as a wheel, a lever, and an inclined plane.



You can go on with this sort of analysis until the idea is firmly grasped by the class.

CONCEPT: Magnetism is a force which travels through space without an apparent carrier.

ACTIVITY 1. That Invisible Push and Pull

Introduction

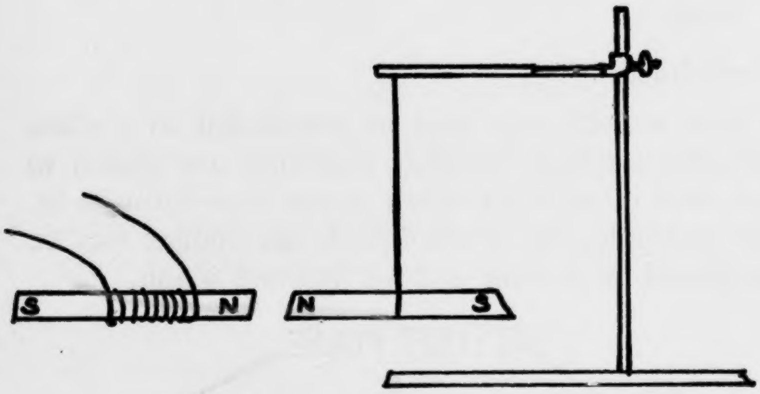
In this activity the attempt is made to lead the pupil to certain observations about the attraction and repulsion of magnets.

Materials

20 bar magnets
string
10 ring stands
10 ring clamps

Procedure

Divide the class into 10 or more groups and give each group a ring clamp, a ring stand, a string, and two bar magnets. Have each group suspend a bar magnet by a string so that it swings freely.



Ask the groups to use the second magnet to answer the following questions:

1. What happens when the end of the magnet marked "N" is held near the end marked "N" of the suspended magnet?
2. What happens when the ends marked "S" are placed close together?
3. What happens when an "N" marked end is held near an "S" marked end?
4. What happens when one magnet is held under the other magnet but at right angles to the suspended magnet?

Discuss the results in terms of attraction of unlike poles and repulsion of like poles. Discuss the phenomena of magnetism as the name given for the ideas we have observed. Stress the directional nature of the magnets.

Ask if anyone knows why one end of a magnet is marked "N" and the other end "S". "N" means north-seeking and "S" means south-seeking.

Ask how one magnet is able to affect another magnet. This question will be dealt with further in the next unit. Do not answer it now.

ACTIVITY 2. Force Fields

Introduction

The force field around a magnet is not an explanation of the type called for at the end of Activity 1, but it will help the pupils to picture magnetism and magnetic fields.

Materials

10 bar magnets
iron filings
8" x 11½" sheets of white paper
1 spray can of clear acrylic or clear lacquer

Procedure

Divide the class into five groups and direct them to place a bar magnet under a piece of paper. Have them sprinkle iron filings over the paper. Spray each paper with a light covering of clear coating over the filings and let dry. Repeat this procedure, using two bar magnets with opposite ends attracting, and again with like ends opposing. When each group has finished, the paper is a record of the data on the force field of the magnets.

Discuss the data with the class. Lead the pupils to conclude that the particles of iron align themselves with the force field; hence the outline of the field. Note that the field of a magnet is directed from pole to pole of the same magnet but when the "S" pole of one magnet is placed near the "N" pole of a second magnet a field develops between the two magnets. This is not the case when like ends are placed close together.

ACTIVITY 3. Force Fields Have Direction

Introduction

In Activity 2, members of the class observed the lines of force that rise at the ends of the magnet and travel through space to another magnet end of opposite nature. In this activity, the pupils will use a compass to find the direction of a force field, and explain why a compass works.

Materials

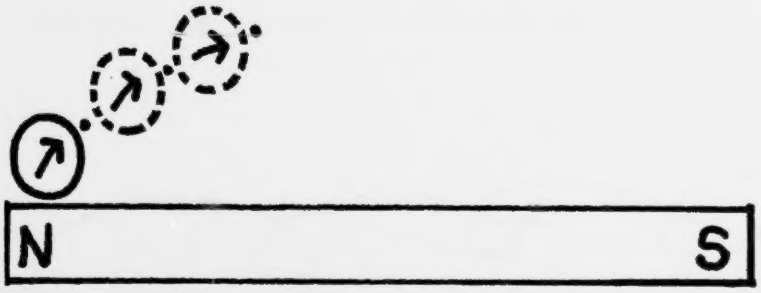
- 5 small compasses
- 5 bar magnets
- 5 large pieces of paper
- 1 piece of iron metal (scissors, paper)

Procedure

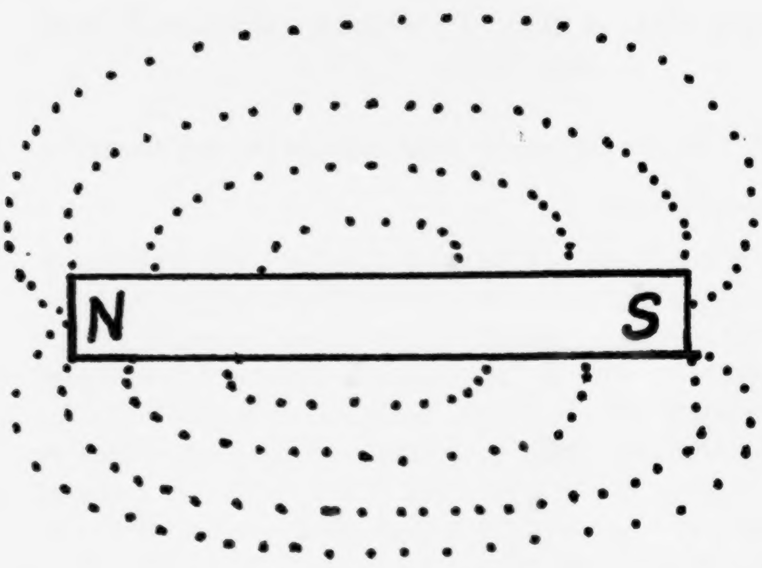
Divide the class into five groups. Give each group a large piece of paper and a compass. Have each group place its paper on a flat surface (the floor will work if tables are not available).

Ask what the pupils know about a compass. They will likely say that it points north. Determine north for the classroom and have each group check the surface where they will work. Ask them to determine whether their compasses all point north over the entire surface of the paper. Ask why this is necessary. Give each group a piece of iron metal to put on the paper. Ask the groups to move their compasses near the metal (their area must be free of pieces of metal to avoid the interaction of the compass with metal).

Some pupils may need to move to an area where there is no interaction between compass and metal. Direct them to place the bar magnet on the sheet of paper and with a pencil (ball point pens might be made of metal) direct them to place the compass at any point near the magnet. Put a dot on the paper at both ends of the compass needle. Then move the compass so that one end of the needle points at one of the two dots. Put a dot at the other end and so on as illustrated below.



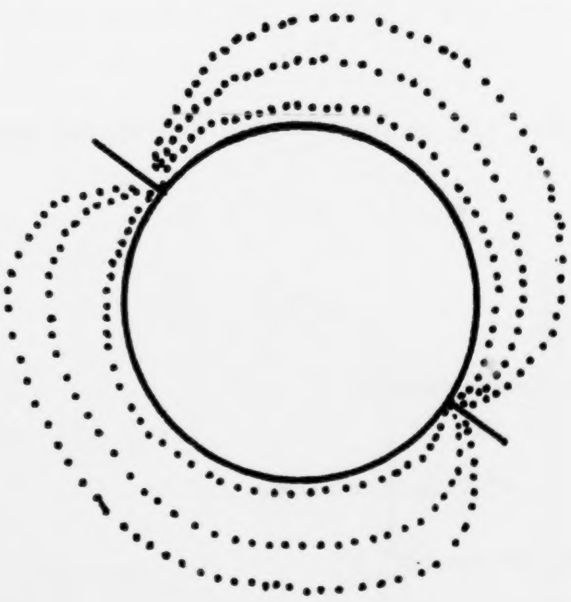
When they have traced one line away from and back to the magnet, have them begin again so that in the end they will have a picture of the magnetic field similar to the one at right above.



Discuss the results. Considering the bar magnet suspended in Activity 1, ask who can tell what a compass needle is. It is a magnet. It has a "north-seeking" pole and it points to the "north" pole of the earth. Ask which pole of the magnet the compass points toward. From their previous experiments, remind the class that unlike poles attract. Hence one says the "north-seeking" pole of the compass is attracted to the "south-seeking" pole of the magnet.

Ask why a compass points toward the "north pole." This is because the earth is a gigantic magnet with a pole we call north. Tell the pupils to draw a circle on a piece of paper and pretend that it is the earth. Have them predict by drawing what the lines of force would look like around the earth.

A sketch like the one below should be produced.



Ask why a compass points toward magnetic north. Because it aligns itself with the magnetic force field around the earth.

CONCEPT: A flow of electricity produces a magnetic field.

ACTIVITY 1. Magnetic Field Around Moving Electricity

Introduction

The concept of magnetism was dealt with previously. Some interesting examples were given. However, modern society as we know it would not be possible without the magnetic fields of force produced when electricity flows. This is the basis for the operation of all electric motors. Closely tied to this idea is the fact that when magnetic lines of force cross a conductor they produce in it a flow of electricity. The following activity is designed to lead the pupil to some of these conclusions.

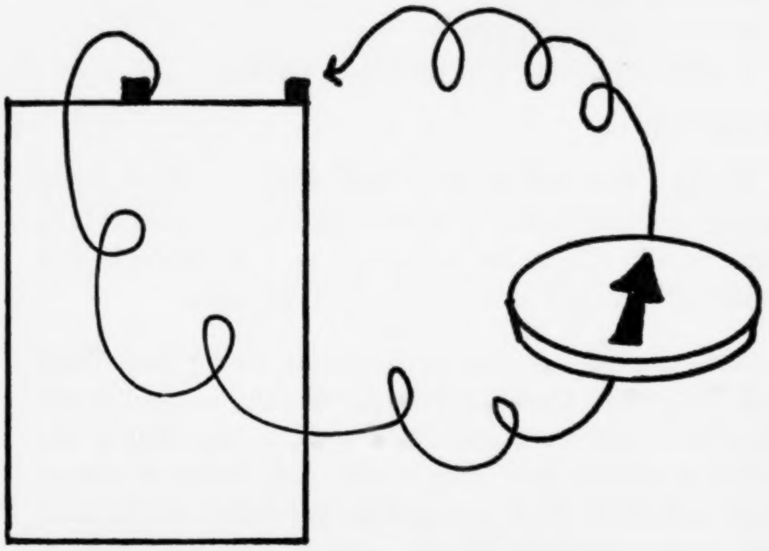
Materials

#28 gauge cloth insulated wire
5-6 batteries (1½ dry cell)
3 small compasses
ring stand
2 utility clamps
2 corks

Procedure

Divide the class into five groups and direct them to take a piece of the wire, clean off the ends, and attach one end to a battery pole. Place the compass on a non-magnetic surface and observe that it points north. Place the center portion of the wire over the compass and touch the loose end of the wire to the other battery terminal as illustrated below.

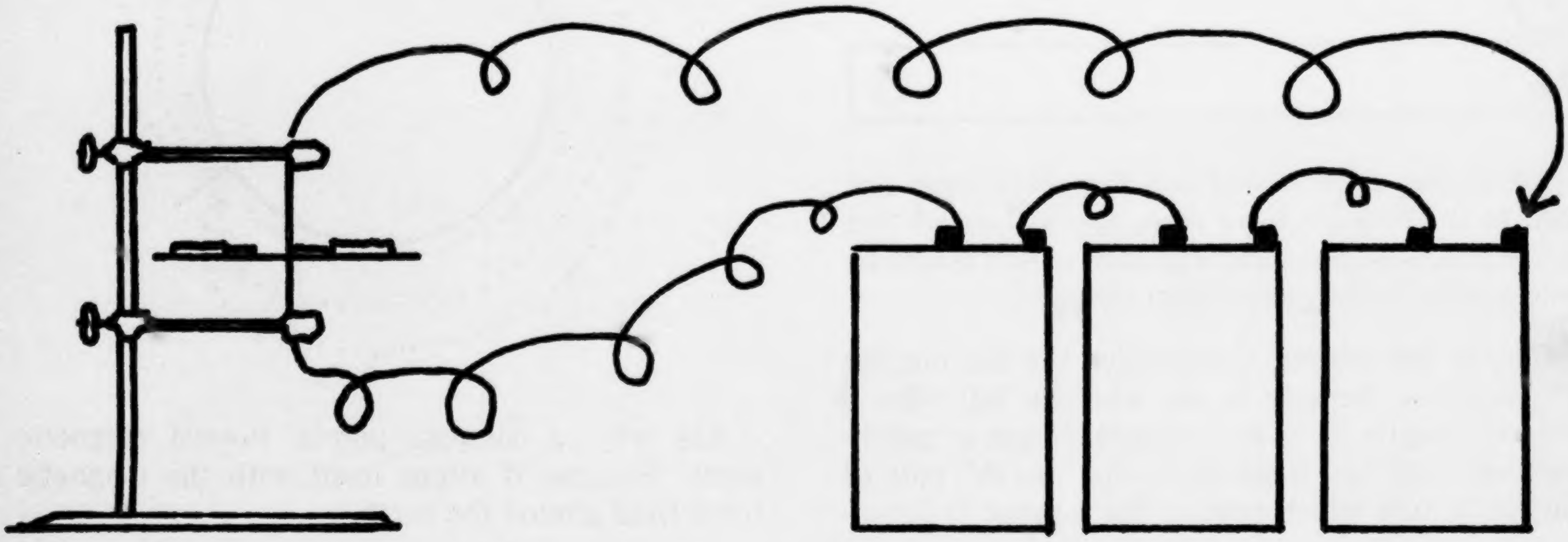
CAUTION: The contact should not be too long as the battery will soon be "discharged." The observation can be made in a few seconds.



The needle will deflect at right angles to the flow of electricity. Ask what happens. Review the fact that compasses tend to line up along the lines of force. How are the lines of force directed near this wire? They seem to be at right angles. Now have the pupils reverse the connections on the battery. This will cause the electricity to flow in the opposite direction. Be sure they do not reverse the wire over the compass. Ask what they observe. Have them reverse the connections again to check themselves. Lead the class to the following conclusions:

1. The flow of electricity produces a magnetic field with lines perpendicular to the wire.
2. The lines reverse direction when the electricity flow is reversed.

Attach three telephone batteries as indicated below:

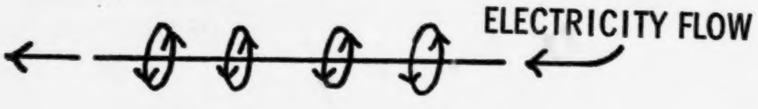


Run wire through two corks and the center of a cardboard. Place four small compasses around this wire and connect to the face terminal for a brief period. The needles should deflect as indicated in the illustration.

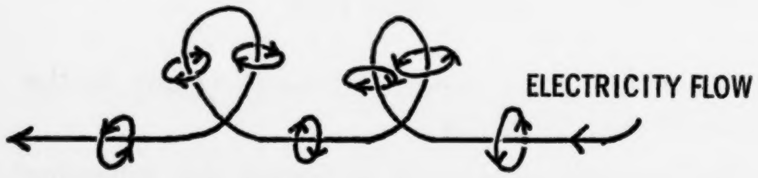
Lead the class to conclude that the force field is circular around a conductor as well as being at right angles.

Reverse the wires A and B and demonstrate that the field direction is reversed.

Draw this picture on the board to represent the force field around the wire.



Ask what would happen if we made a coil of the wire.



Lead the pupils to understand that when the wire is wound onto a coil the lines of force are concentrated. Since the electricity is all flowing through the wire in the same direction, all magnetic fields of force are in the same direction and they add to each other as indicated in the sketch above. On the inside of the coil they all point to the right. Around the outside, the lines are all directed to the left. Since the coil produces strong lines of magnetic force, it is a magnet, and since it is produced by electricity it is called an electromagnet.

Direct each group to take a 10-foot piece of wire and make 10 coils 3-5 inches in diameter, and connect one end to the terminal of one telephone battery. Place the compass at one side of the coil. Connect the other wire and note the deflection of the compass needle. Reverse the connections on the batteries without reversing the coil. Observe and discuss the results with the class.

ACTIVITY 2. Work from an Electromagnet

Introduction

In this activity an electromagnet will be used to show that it can exert force on an iron nail.

Materials

a large test tube
#28 insulated wire
telephone batteries
an iron nail about 3 inches long
a small cork

Procedure

Demonstrate the following to the class: Ask some of the pupils to help you. Wrap 200 turns of wire around the test tube about 1/3 of the way up from the bottom of the tube. Insert the nail into the cork as far as it will go. If it does not float, use a larger cork. If it does float, be prepared to slice off a piece of the bottom of the cork with a sharp knife. Connect one end of the wire to one terminal of the battery. Fill the tube about 2/3 full of water and place the nail in the water. Connect the other terminal briefly. The nail should dive. This can be repeated by several youngsters.

Emphasize that the magnet exerts a force on the nail attracting it into the coil.

ACTIVITY 3. Using a Magnet to Generate a Current

Introduction

Thus far emphasis has been on magnetism as a product. Particular emphasis has been given to producing magnetism with a flow of electricity. Now the reverse side of the same coin must be emphasized. When a conductor is passed through a magnetic field of force, electricity will be caused to flow.

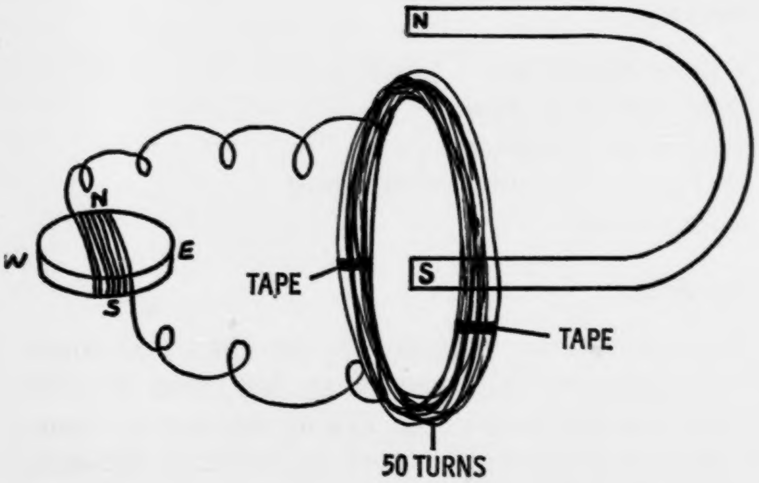
Materials

5 horseshoe magnets
bell wire
5—100 ml. beakers
5 compasses
tape

Procedure

Divide the class into five groups. Have each make a coil of 50 turns of bell wire around a glass tumbler or 100 ml. beaker. Slip the coils of the beaker and fasten it with tape so that the coil will not come apart.

Have each group wrap a compass with a dozen turns of bell wire. Use tape on the edge to secure the wire in place.



Move the magnet with one pole through the coil. Note which way the needle deflects. Pull the magnet out. Notice which way the needle deflects. Reverse the poles on the magnet and tell the class to repeat the procedure, taking note of the results.

Tell the class that electricity generators employ this principle in city power plants and hydroelectric dam sites.

ACTIVITY 4. A Difference Between Magnetic and Geographic Poles of the Earth

Introduction

In Activity 3, pupils develop the idea that the earth has a magnetic field and a north and south magnetic pole. This activity serves to illustrate the difference between the north and south geographic poles and the north and south magnetic poles.

Materials

magnetic compass
ruler
protractor

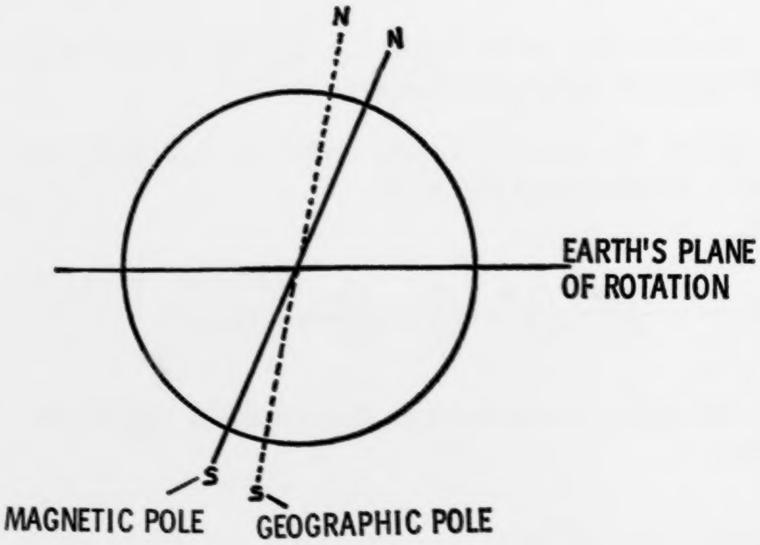
Procedure

This activity should be completed in groups of two to four pupils per group.

The teacher has the important task of drawing a true north-south line or lines on the school grounds. If you have a magnetic compass, correct it for the magnetic declination at your locality (declination may be obtained from local topographical map). Use the corrected compass to determine a true north-south line. Draw one or several north-south lines on the playground.

Have the pupils take the magnetic compass and align it with the north-south line. Do the compass needle and the north-south line point in the same direction? If not, measure the angle between the needle direction and the north-south line. Why is there an angle? Is there more than one north-south pole?

Ask pupils to draw a model of the earth showing the relationship between the north-south magnetic poles and the north-south geographic poles. (See diagram.)



Would the angle between these two poles be the same all over the earth?

The teacher may wish to assign the following topics for reports and discussions:

1. What is declination of the earth's magnetic field?
2. What is the origin of the earth's magnetic field?

CONCEPT: All objects are pulled or attracted to each other by the force of gravitation.

ACTIVITY 1. What is the Effect of the Earth's Force of Gravitation on Objects?

Introduction

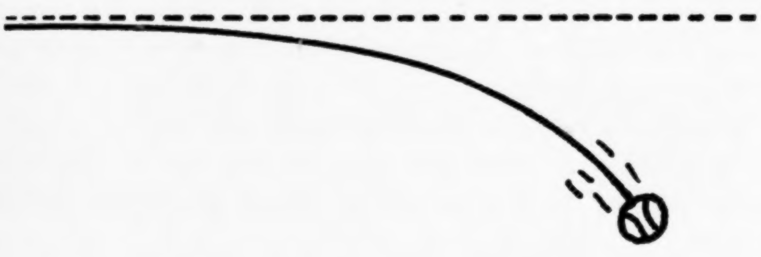
All objects are pulled or attracted to the earth by the force of gravitation, and all objects pull or attract the earth. This activity investigates, in a very simple fashion, how this force acts on various objects. You cannot see this force, yet you know it is there—acting on a ball, the moon, and all other objects.

Materials

ball (tennis ball or similar type)
4-foot piece of string
ball, eraser, or any weight

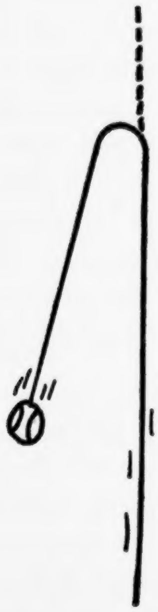
Procedure

Part A. This part may be performed by the teacher or one or two pupils with the remainder of the class making their own observations. Throw a ball straight out (horizontally) many times and have pupils observe its path carefully. Have them make a drawing of the path of the ball.

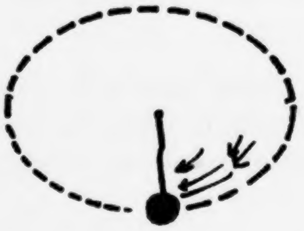


Why did not the ball continue to move in a straight line path? What force was acting on the ball to change its motion?

Throw the same ball straight up. Why did not the ball continue moving in a straight line? What force was applied to change its motion? In what direction is the force acting?



Part B. Tie the string and weight together. Holding the string tight, start the weight moving at a steady speed in a circular path around your head. Whirl it around just fast enough that the weight and string are nearly horizontal. Draw a diagram of the path taken by the weight. Explain why the weight moves in this path.



Discuss the force relationships between this model and the earth-moon system. The weight is the moon, and the string represents the earth's gravitational pull on the moon. What is the force pulling the weight toward the center? What is the force which exerts a pull outward? What will happen if you let go of the string? Draw the path that the object will take if the weight is allowed to fly off.

What object pulls on the earth in the earth-sun system? What force is involved? Why doesn't the earth continue to move in a straight line instead of in its elliptical path?

Part C. This part involves library research concerning the force of gravitation. Any appropriate phase of gravitation which leads to an understanding of the concept should be searched out by the pupils. The questions listed below are mere suggestions and represent only a few ideas concerning gravity as a force:

1. What is the relationship between mass of bodies and the amount of attraction between them?
2. Why does the force of gravity of the moon, sun, and other planets differ from that on earth?
3. What effect does the moon's gravity have on the earth? (Primarily—study of earth tides.)
4. What escape velocity is needed by a rocket to escape the earth's gravitational field?
5. What is Newton's Law of Universal Gravitation?
6. Is the force of gravity the same at all points on the surface of the earth?
7. What is the influence of distance between bodies on the amount of the gravitational attraction?

Allow the pupils to develop a discussion based on these and other topics of interest. The teacher should entertain any appropriate topic in the discussion to maintain interest. The pupils may wish to demonstrate something or make drawings and models to aid in their participation in the discussion.

CONCEPT: Weight is a measure of the force of gravitation on an object.

ACTIVITY 1. What is the force of gravitation on an object, or how much does an object weigh?

Introduction

Weight is investigated as the measure of the pull of gravity on objects. The pupils have used units of weight to weigh many objects (including themselves). However, many pupils do not relate weight to a force. This activity serves to correlate weight with the force of gravitation.

Materials

equal-arm balance
spring balance
empty half-pint carton
water or sand

Procedure

Groups of four pupils each (depending on availability of the equipment) will work satisfactorily. Using the equal-arm balance, direct pupils to fill the carton with water or sand so that it balances a 200 gram weight. Why do the objects balance? Is it because each weighs the same, or because there is an equal force pulling on each substance?

Now have the pupils take the 200 gram weight off the balance and observe the results. Why does the carton of water or sand move down? How much force of gravitation acts on the carton of water or sand?

Use the spring balance to weigh the carton of water or sand. This will serve to illustrate why the materials weigh 200 grams. The spring balance represents a measure of an opposing force so that when the forces are balanced you are measuring the force of gravitation.

Discuss what occurs when pupils weigh themselves on a scale. What are they measuring? What force pulls them down?

ACTIVITY 2. Do You Always Weigh the Same?

Introduction

With a constant mass, the weight of an object may change. This change is related to the force of gravitation. The purpose is directed toward weight changes and the force of gravity with little or no emphasis on the weight-mass problem.

Materials

pencil
paper

Procedure

This activity should be conducted individually, followed by a class discussion to correlate and investigate the results.

In Activity 1, pupils were introduced to weight as a measure of the pull of gravity. Is the measure of the pull of gravity the same all over?

Suggest that the moon, being an object with a particular mass, would attract the individual just like the earth. Would the person weigh the same on the moon as he does on the earth? Because of the mass of the moon, its pull of gravity is only about one-sixth that of the earth. On Mars, the pull of gravity is one-third that of the earth, but the sun's pull of gravity is 26 times as much as the earth's.

Ask pupils to calculate their weight on the moon, Mars, and the sun. This should emphasize the idea that the weight of an object is related to a force — the force of gravitation. Weight changes with a change in the force of gravitation.

Does an object weigh the same at all places on the earth? The teacher may introduce distance as a factor in the determination of weight. The higher you go above the center of the earth, the smaller the force of gravity. In fact, a person would weigh less on top of a high mountain than at the base of the mountain. At 8,000 miles above the earth a person's weight is only one-fourth as much as at the earth's surface; at 16,000 miles, one-sixteenth as much. Direct the pupils to calculate their weights at these altitudes. Discuss the relationship between the force of gravitation and the distance between objects.

Some members of the class might be interested in the investigation of increasing one's weight. Pupils may have heard about tremendous forces called "g's." A "g" is simply a force equal to the earth's gravity. The "g" force on a pupil is his own weight. How do the "g" forces increase? When the "g's" increase, why does weight increase?

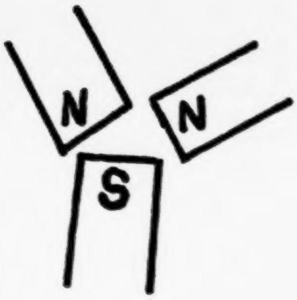
EVALUATION

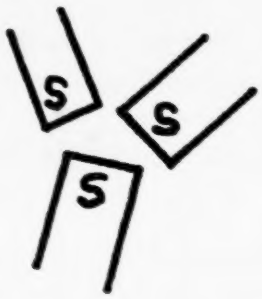
For purposes of evaluation the teacher should design questions which call for application of the principles presented in the activities. Develop the situation presented in the problem so that it appears similar to the activities but has one or two different ingredients.

Examine each goal carefully. Set up a test situation which attempts to determine whether the goal as stated has been achieved. Some suggestions follow:

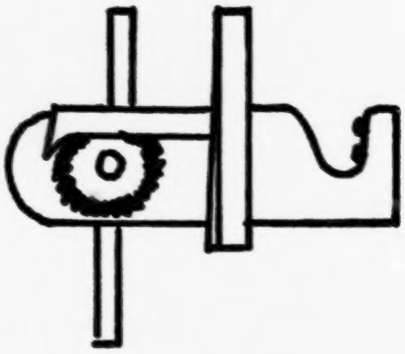
1. Suppose you were given a small compass, a large piece of paper, and an iron washer. Draw a picture indicating how you would expect the force field around that washer to look if you plotted it using a compass.

2. In the activities of this unit you sprinkled iron filings over sheets of paper. Under the paper you placed two magnets. Suppose you had used three magnets oriented as below and sprinkled iron filings over them. Predict the direction of the force field by drawing in lines to represent the lines of force.





3. Draw a picture of a common complex machine such as below and ask the pupils to identify the simple machines that make up this complex machine. A hand can opener would be an example.



4. Suppose an object were weighed on earth and found to weigh 10 pounds. Jupiter is a more massive planet than earth. Would the object be expected to weigh more, less, or the same on the planet Jupiter? Explain your answer.

BIO-SYSTEMS

IN THE STUDY of biological change, a person must first think about evidence of past life and how it compares with modern life. Most evidence of past life is found in the form of fossils and it is by *interpreting data* that hypotheses are formulated which attempt to explain change.

As this system is studied it is important that the teachers always try to create situations in which the pupils have an opportunity to *interpret data* and develop hypotheses of their own. Interpreting data and developing hypotheses are complex skills and require the understanding and use of more basic skills such as *measuring, observing, prediction, inferring,* and *recording data.* It is through the skillful direction of the teacher that these more basic skills are developed and utilized as integral parts of the skills that are stressed in this unit.

Unit Goals

Upon completion of this unit the pupil should be able to:

1. Recognize how fossils are formed.
2. Understand that change is always taking place.
3. See that modern life forms have ancient relatives in the fossil record.

Unit Development

This unit is to be developed in four parts: first, a library search; second, a field trip; third, laboratory work; and fourth, library search. Because of the nature of the subject matter, this unit will tend to be less laboratory-centered than the other units in this guide. It is not intended to be less student-centered, however.

The first part of the unit should be a teacher-directed library search to learn the methods of finding, cleaning, and preserving fossils. At this time the class will also wish to decide on a fossil-collecting site for the collecting trip. The collecting site may be as simple as a neighborhood driveway with fossil coral in the crushed rock, or as elaborate as a trip to one of the collecting sites listed later in this unit.

The second part of the unit is the field trip itself; this is the single most important part of the unit. It is here that the pupils should see the actual relationship of fossils to the strata of rock or soil in which they are found.

The third part is the actual laboratory work. Here the pupil should gain several insights, such as how fossils are formed and how the data in the fossils' record is interpreted. Pupils will also have a chance to formulate hypotheses.

The fourth and last part of the unit will be concerned with putting all information gained in the unit into a common frame of reference. It is in this part also that past life will be related as fully as possible with modern forms if such exist.

CONCEPT: Life on the planet Earth is very old indeed. Scientists agree that our planet is over two billion years old. During that two billion years, life on earth has been in a state of constant change, with new species developing and old species dying out or becoming extinct.

It is therefore very important for the pupil to gain an idea of the vast amount of time involved in the fossil record of the earth. This will be very important later in this unit when the pupil tries to interpret the fossil record from fossil specimens and other evidence.

ACTIVITY 1. What is a Billion?

Introduction

The idea of a billion is very difficult to grasp even for adults. The word is used quite loosely in newspapers these days, but unless a pupil is given an opportunity to think about the number (one billion), it probably means very little to him.

Materials

None

Procedure

To initiate this activity, begin with a discussion of a billion. One very good way to get the discussion started is by reading several current newspaper clippings in which the word billion is used. Once every member of the class has had an opportunity to air his opinion about a billion, ask everyone to take a sheet of paper and pencil. Now explain that the modern calendar starts dating time from about 2,000 years ago, or the year 1 A.D. Explain also that you would like the class to consider an imaginary person that had one billion dollars and started spending at the rate of one thousand dollars per day. If this man kept spending one thousand dollars every day for two thousand years, how much money would he have left?

365 (days in a year) x 2,000 (years money has been spent) x $1,000 (money spent every day) = $730,000,000

$1,000,000,000 (original one billion)

$ 730,000,000 (money spent in 2,000 years)

$ 270,000,000 (money left)

After the class has had enough time to work the problem, have someone with the correct answer put the problem on the board and explain it.

Finish this activity with a discussion, pointing out the standard of living one thousand dollars a day would provide and the number of normal life spans that 2,000 years would include.

ACTIVITY 2. Time Line

Introduction

A time line will often aid a pupil in recognizing chronological order. Certainly the research and effort that goes into building a time line is a valuable experience.

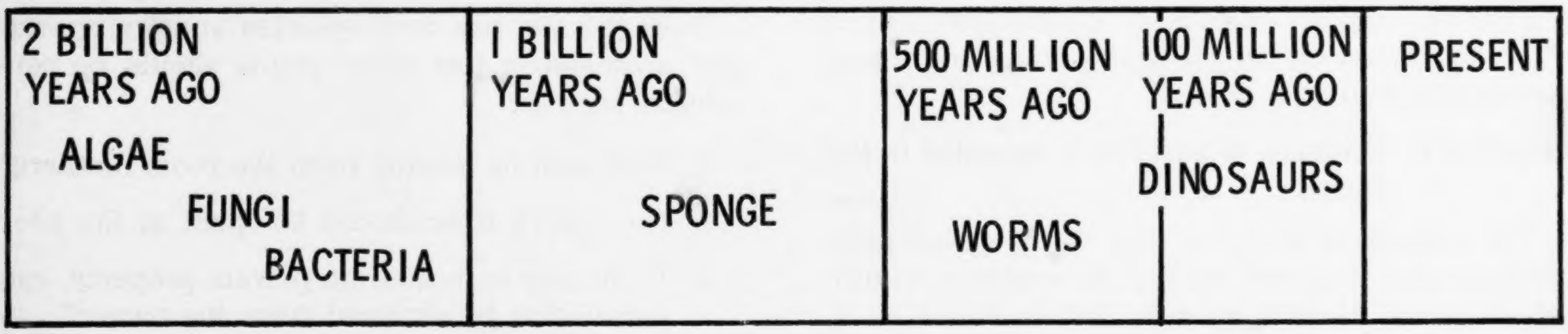
Materials

papers
paints

Procedure

With library books and personal books brought from home, have the class do the research necessary to plan and build the time line of the earth's history.

If possible, the time line should run the length of the classroom and be made from wrapping paper so that it can be one continuous piece. Two billion years is the figure that the class will come up with for the age of life on earth; however, there is no real agreement on the exact time even among scientists. The names of geological eras should not be stressed at all and would better be left off the time line. Instead of eras, the number of years past should be listed with a picture of the dominant animal of that time.



The teacher might wish to make another time line for just the last 100 million years. This can be the same length as the first time line and posted just under it. If the teacher has the class build this second time line, he should be sure that the class understands this is just the last 100 million years of the first time line, expanded.

100 MILLION YEARS AGO	50 MILLION YEARS AGO	25 MILLION YEARS AGO	6 MILLION YEARS AGO	3 MILLION YEARS AGO
DINOSAURS GINKO TREES	SIMPLE MAMMALS	HORSE	MAN	

After the time lines have been completed, they should be left for reference and study throughout the rest of the unit.

ACTIVITY 3. Library Research

Introduction

This activity is to be used to prepare the class for the field trip later in the unit and should not be any longer than necessary to provide this background.

Materials

None

Procedure

From the local library and from the school library, the teacher should borrow as many books on fossils as possible and make them available in the classroom. Pupils should be encouraged to bring in their own books and share them with the rest of the class. From these books class members should make themselves familiar with fossils, methods of fossil collecting, and methods of fossil preservation.

Pupils should have a general idea of the types of fossils available in the area. Once the pupils have had adequate time to conduct their library research, the activity should be culminated with a class discussion in which ideas, knowledge, and viewpoints should be shared.

CONCEPT: Evidence of past life is recorded in the rocks.

The science of studying past life is called paleontology and depends mainly on evidence of life left in rocks. Iowa is an area rich in this type of evidence — fossils. In fact, Iowa is the best known source of certain types of fossils in the world.

ACTIVITY 1. Collecting Fossils

Introduction

Almost every town or city in Iowa is located within field trip distance of a good source of fossils. The actual experience of collecting will make the study of fossils much more meaningful; therefore, every effort should be made to take the class on a collecting trip.

Materials

1/2 inch metal chisel
small hammer
magnifying glass
collecting boxes
notebook

Procedure

The first thing the teacher should consider is where to take his class on the collecting trip. The collecting site might be as elaborate as a quarry or gravel pit, or as simple as a crushed rock driveway right in the school's neighborhood. Once the teacher has decided on a collecting site, the next item that would be wise to consider would be a local resource person. If you can find a person in the community who is knowledgeable on the subject of fossils, collecting will be much easier and more profitable for all concerned.

Once the site has been selected and transportation arranged, a few other points should be considered, such as:

1. Will help be needed from the room mothers?
2. How much time should be spent at the site?
3. If the site is located on private property, can permission be obtained from the owner?

4. How will pupil questions be recorded for later discussion?
5. Should pictures be taken as part of the record?

When the class has returned from the collecting trip, every effort should be made to identify the animal and the part which has been fossilized; e.g., shell of a clam. This activity should be culminated with each pupil displaying his fossils for the rest of the class. Fossils should be labeled to show the following information:

1. Name of collector
2. Where collected
3. Type of plant or animal
4. Date of collection
5. Part of animal or plant preserved

The fossils should be saved for the next activity.

Fossil-collecting Areas in Iowa

The following list, although far from complete, includes a few of the better fossil-collecting areas in Iowa:

1. Rockford Brick and Tile Company pit. (½ mile south and ¼ mile west of Rockford, Floyd County, on county road "D") At this location there is an abundance of very well-preserved brachiopods, gastropods, and corals. They are most abundant in the yellowish shales that overlie the blue-gray beds. The fossils occurring here are known as the Hackberry fauna and have been described by C. L. and M. A. Fenton in a book entitled, *The Hackberry State of the Upper Devonian*, published by the Macmillan Company in 1924.

2. Bird Hill. This hill is located near the center of the north line Sec. 24, T. 95N., R. 19W., Cerro Gordo County, and is about 3½ miles west and ½ mile south of the Rockford Brick and Tile Company plant. The same fauna can be collected here as at the Rockford Brick and Tile Company plant.

3. Elgin-Clermont area, Fayette County. In the Elgin member of the Maquoketa formation there are found large trilobites and both straight and coiled cephalopods. Fragments of trilobites are common; whole specimens are difficult to find. Road cuts along the new highway between Clermont and Elgin, the dry stream bed along county road "Y" east of Clermont, and the high-road cuts along the Turkey River southeast of Elgin are all good collecting sites. References for this area are: (1) Slocum, A. W., "Trilobites from the Maquoketa Beds of Fayette County, Iowa," Iowa Geological Survey Annual Report, Volume 25; (2) Walter, O. T., "Trilobites of Iowa and Some Related Paleozoic Forms," Iowa Geological Survey Annual Report, Volume 31; (3) Ladd, H. S., "Stratigraphy and Paleontology of the Maquoketa Shale of Iowa," Iowa Geological Survey Annual Report, Volume 34. These volumes are out of stock in book stores but are available in many public and school libraries.

4. Graf Station, Dubuque County. At the little station of Graf there is exposed a portion of the Maquoketa formation that is literally crowded with straight cephalopods. Graf is located about 8 miles west of Dubuque on a county road about 1½ miles north of Highway 20. It is on the I.C.R.R. This site is described in detail in reference No. 3 of location No. 3.

5. Mill Creek. Along Mill Creek, at Bellevue, Jackson County, (about 1,000 feet upstream from the highway bridge), in the thin, dark shale just above the rock in the stream bed, there can be found what is known as the "depauperate fauna." This is an assemblage of small, phosphatic fossils that are all about 1/2 normal size. The inexperienced collector must look carefully to find them. This fauna is described in reference No. 3 of Location No. 3.

6. Le Grand Quarries. About one mile north of where Highway 30 enters the west city limits of Le Grand, Marshall County, are several quarries commonly known as Le Grand Quarries. In these quarries some of the finest crinoid specimens in the world have been found. They are difficult to find, however, and many hours of work are required to prepare the specimens before they are ready for study or display. Reference: Laudon, L. R., and Beane, B. H., "The Crinoid Fauna of the Hampton Formation at Le Grand, Iowa, "University of Iowa Studies in Natural History, Volume 17, No. 6.

7. Gilmore City area. Just northwest of the town of Gilmore City in Pocahontas County, several quarries have been opened in the Gilmore City formation. Both corals and crinoids are found in these beds but, as at Le Grand, a great deal of work is required to prepare the crinoids. Reference: Laudon, L. R., "The Stratigraphy and Paleontology of the Gilmore City Formation of Iowa," University of Iowa Studies in Natural History, Volume 15, No. 2.

8. Quasqueton area. In the talus along the bluff south of the Wapsipinicon River and two miles west of Quasqueton in Buchanan County, good horn corals can be found in abundance.

9. Southeast Iowa. The Mississipian rocks of southeast Iowa provide a variety of good fossil specimens. In the Burlington formation, near Burlington, Denmark, or Augusta, one can find large brachiopods, fish teeth, crinoids, and blastoids. Collecting here is not as good as at locations 1 and 2, but careful searching will reward one with some excellent specimens. References for the Mississippians include (1) Van Tuyl, F. M., "Stratigraphy of the Mississippian System in Iowa," Iowa Geological Survey Annual Report, Volume 30, (2) Landon, L. R., "The Stratigraphy of the Kinderhook Series of Iowa," Iowa Geological Survey Annual Report, Volume 35.

10. B. L. Anderson Quarry. At a quarry northeast of Vinton located SE cor. Sec. 10, T. 85N., R. 10W., Benton County, large spirifers can be collected as well as atrypa and the colonial coral hexagonaria. This coral is often cut and polished and is called "Birds-eye marble."

11. Lake McBride Spillway. Near the spillway of Lake McBride, about 10 miles north of Iowa City, both brachiopods and corals can be collected.

12. Red Oak-Stennett area. At quarries near Red Oak and Stennett, both in Montgomery County, one can find a band of dark brown to black chert generously peppered with the small white fusulinid triticites. This specimen is interesting paleontologically, and the chert polishes very nicely.

13. Plum Creek. For those interested in collecting fossil plants, there is a good collecting area located along Plum Creek in NE¼NW¼NW¼ section el, T. 70N., R. 42W., Fremont County. This is one mile east and one mile north of the town of Thurman.

14. Westerville section. In Madison County, SW¼NW¼ sec. 13, T. 75N., R. 26W., there can be found in an argillaceous limestone an abundance of chonetes and crurithyris.

ACTIVITY 2. Reconstruction of the Past

Introduction

A large part of the paleontologist's job is concerned with trying to reconstruct the past as completely as possible from the fossils he finds. Often he can draw a very accurate picture of the climate, environment, and other plants and animals that lived with the fossil. This is what the teacher should try to have the class do in this activity, relying on the adage that "the present is the key to understanding the past."

Materials

magnifying glass

fossils for field trip

other fossils that might be available

the handbook, **Fossils,** a guide to prehistoric life by Golden Press, New York ($1.00)

Procedure

With the fossils that have been collected and any others available, divide the class into as many groups as needed. Instruct each group to try to determine from their fossils the following:

1. How old is the fossil?
2. What part of the animal is the fossil?
3. Does the fossil have any modern relatives? If so, what does that plant or animal look like?
4. What was the climate like when the fossil was alive?
5. What were the surface conditions when the fossil was alive?

It will probably not be possible to answer all of the preceding questions about each fossil, and it might not be possible to answer any of them for some of the fossils. This is exactly the case with a scientist, but with many fossils and much study a picture of the past does emerge.

Culminate this activity with a class discussion in which the members of each group have an opportunity to share what they have learned.

ACTIVITY 3. Evidence of the Past

Introduction

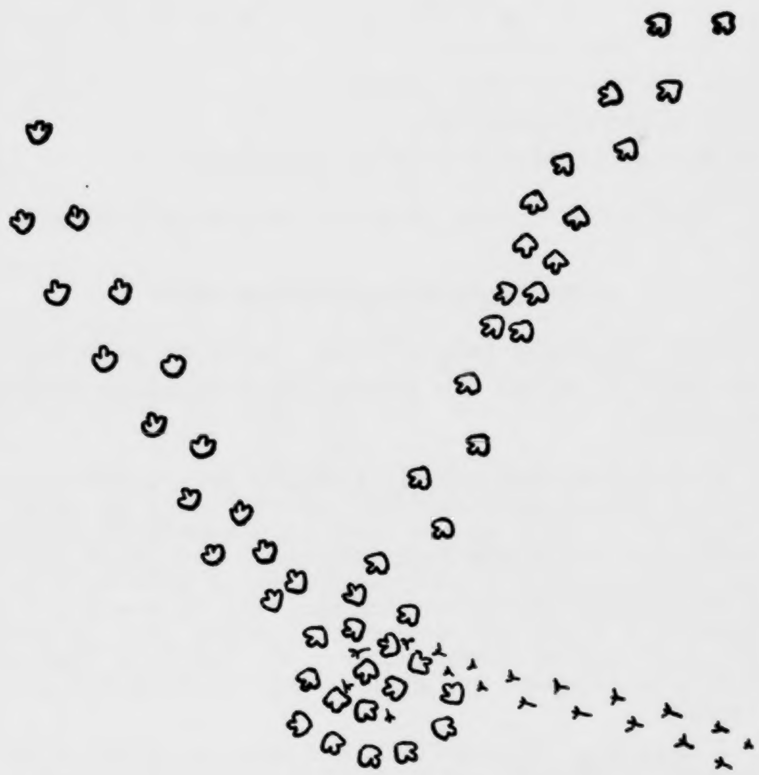
Not all fossils are the remains of bones or other hard parts. Some are merely evidence that an animal has been there. In this activity the pupils will have an opportunity to work with that kind of evidence.

Materials

overlays

Procedure

Divide the class into several groups and provide each group with a copy of overlay No. 1 and tell them these are fossil animal tracks similar to some that have already been found.

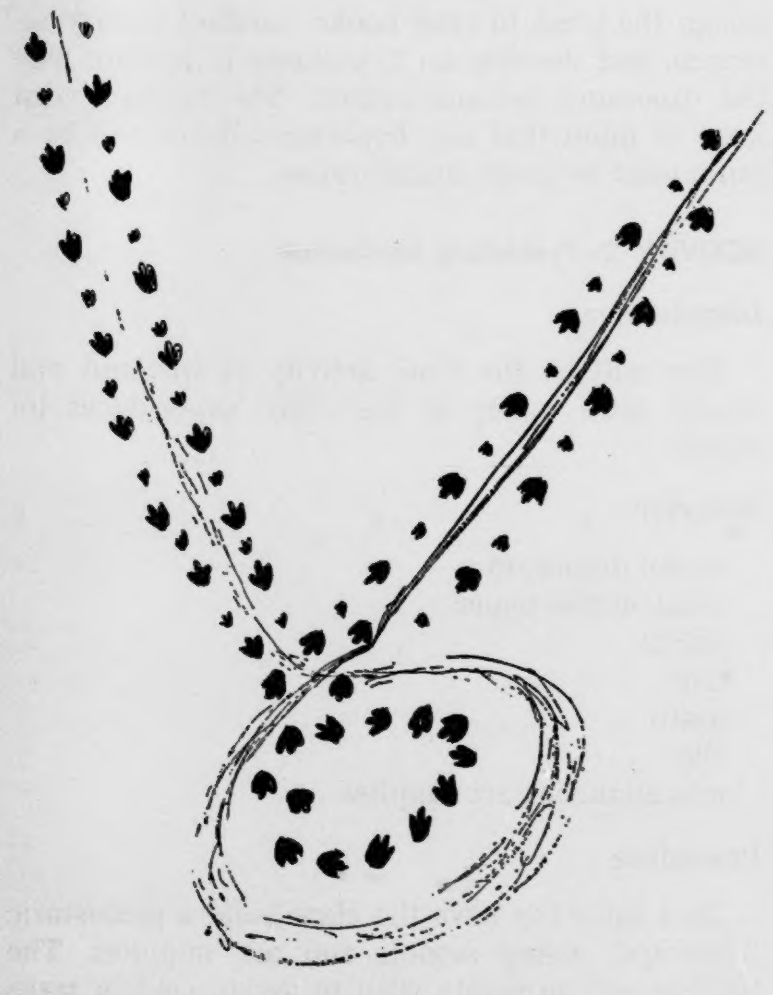


Tell the class to study these tracks and see if they can tell what was happening when they were made. Do not give them any hints, but bear in mind that there is no *correct* interpretation. Some theories that might come up are:

1. Big animal ate little animal.
2. Little animal was a bird that was scared away.
3. Little animal jumped on the back of big animal and rode away.
4. Big animal killed little animal and carried it off.

When each group has a theory, the groups should share their theories in discussion.

Next class period, repeat the same procedure with overlay No. 2.



ACTIVITY 4. How Fossils Are Formed

Introduction

This activity will be concerned with helping the pupil understand how some types of fossils are formed. It will deal with only two of the several methods by which fossils are formed in nature, cast, and mold.

Materials

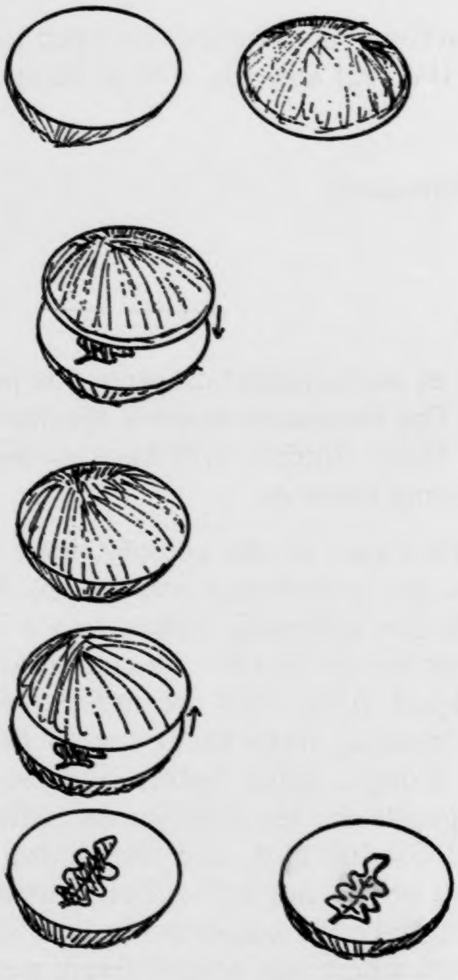
talcum powder
clay
leaves
clam shells
plaster of paris or patching plaster
paper
paper clips

Procedure

Divide the class into as many groups as you have material for; ideally, each child should be allowed to make a "fossil." Give each group a large piece of clay, a leaf, and a container of talcum powder. Instruct the pupils to pound out two flat pieces of clay about 3/4 of an inch thick and five or six inches in diameter. Have them powder one side of each piece of clay with the talcum powder. Now they should place the leaf on the powdered side of the piece of clay and cover it with the other piece so that the powdered side of each piece is against the leaf.

Have the pupils press the pieces of clay together firmly. Once this is done the pieces should be gently pulled apart and the leaf removed. The result will be an impression of the leaf in the clay.

At this point ask the class to try to develop an idea of how this activity might explain one way in which real fossils might be formed. Have them discuss this first in small groups and then as a class. During the discussion the teacher might point out that hardened clay is the rock shale and that many fine fossils do come from clay in nature.



CONCEPT: Plants and animals become extinct when they can no longer compete successfully.

The life web on earth is vast and complex and when one part of the web is altered it affects the whole web. Much of the life web of prehistoric times is lost to us because it did not leave a record in the rocks, or if it left a record, paleontologists have not learned

to interpret the record. It is therefore not possible to look back and say exactly why any major group of animals becomes extinct. The scientists form theories to explain why most animals became extinct, but these are only theories. In this part of the unit we will deal with dinosaurs, a very major group of animals, now extinct.

Through library research, we will try to develop a picture of their beginning, their reign as a dominant group, and their extinction.

ACTIVITY 1. Model Dinosaurs

Introduction

In this activity the likeness between model dinosaurs and the real animals will be compared.

Materials

model dinosaurs
clay
paints

Procedure

Provide as many model dinosaurs as possible for the class. The secondary science teacher generally has some. Many children will have models and will enjoy bringing them in.

In the first part of the activity, have the pupils go through the models and remove any which they do not feel are authentic (there very well may be some). They can do this from a search of the books on the subject. After they are satisfied that all are authentic models, have them try to divide them into two groups, plant eaters and meat eaters. Have the pupils discuss whether each dinosaur was well-suited for his diet, and the reason why they think it was or was not well-suited. During the next class period have the pupils study their models and speculate on where the animal lived; e.g., in water or on land. These predictions can be checked by using the available books. After the mode of life has been decided upon for each model, a class discussion should follow, giving each pupil an opportunity to air his opinions.

During the next class period, the teacher should assign the class to read books, conduct library research, and develop an hypothesis to explain why the dinosaurs became extinct. The teacher must keep in mind that any hypothesis developed by a pupil must be given consideration.

ACTIVITY 2. Prehistoric Landscape

Introduction

This will be the final activity of the unit and should draw many of the class experiences together.

Materials

model dinosaurs
construction paper
paints
tape
paste
clay
miscellaneous art supplies

Procedure

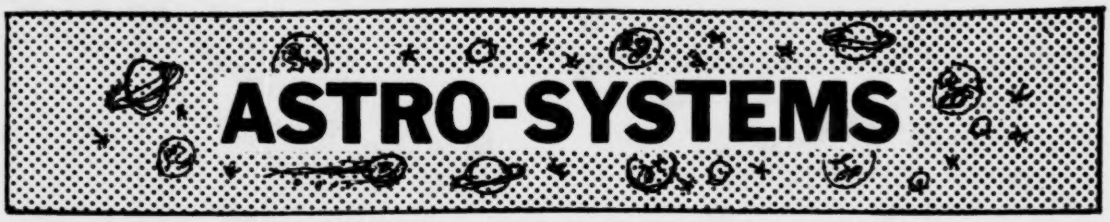
On a table top have the class build a prehistoric landscape, using models and art supplies. The teacher will probably wish to assign certain tasks to different individuals or small groups. The model dinosaurs will work nicely, but much of the plant life will have to be made from scratch. The pupils and teacher should pay close attention to known facts about this period of time and make sure these facts are not ignored. For example, cave men and dinosaurs did not exist at the same time on earth so should not be shown together.

When the table top is completed, it should be discussed. A mark should be placed on the time line made earlier in this unit at about the time when the table top landscape could have existed.

EVALUATION

Do not use a test of fact recall in evaluating this unit. The teaching of facts has not been a major objective of this unit.

One effective method of evaluation could be to have the pupils write a short story about the history of the world or some equally broad topic through which they can put on paper their beliefs, attitudes, and understanding of the topic.



ASTRO-SYSTEMS

THE ASTRO-SYSTEM involves an area which appeals to the natural curiosity of pupils. Capitalizing on this pupil curiosity, the skills of observation, measurement, and inference are utilized to develop the more sophisticated skills of *hypothesis formulation, model-building,* and *data interpretation.* The Astro-System provides a very unusual vehicle for development of these skills.

Reasonable hypotheses regarding the cause of observable phenomena is the goal of hypotheses formulation. Model-building is a skill involving physical and mental representations which account for the phenomena observed. The interpretation of data considers the making of imaginative and comprehensive conclusions. To draw conclusions unsupported by data is a pitfall pupils must avoid.

Realistically, not all pupils are capable of these more sophisticated skills. Nevertheless, pupil exposure to these skills is important to further scientific activities.

Unit Goals

Upon completion of this unit, the pupil should be able to:

1. Understand the earth's place within our solar system and the universe.
2. Recognize orderliness in the changing nature of the universe.
3. Identify our sun as an important star, yet realizing it is only one among billions of stars.
4. Understand how man learns about the universe.

Unit Development

This unit considers the central idea of making observations and measurements leading to hypotheses, models, and inferences concerning the Astro-System.

After locating our position on earth and analyzing the gross shape of this body, the pupil becomes involved with the earth as a member of the Astro-System. Activities are designed to illustrate the observations important to the understanding of such things as planetary motions, apparent motions, and seasons of the year. The moon-earth relationship is analyzed in terms of its most common appearance to an earth observer — that of the phases of the moon.

The developing unit next attempts to establish how we know the temperature, composition, and size of stars. Logically, the activities center around observations of the sun, but the sun is identified as only one of many billions of stars.

An activity concerning nuclear energy is developed to stress the energy-matter interaction theme. The universe is changing as a result of these energy-matter interactions. However, pupil observations throughout the unit should expose an orderliness to this change.

After the teacher analyzes this unit, the lack of breadth of subject material will become apparent. We have limited our subject-matter coverage in favor of extensive pupil involvement in activities to discover how scientists learn about the Astro-System. The teacher should emphasize the formulation of hypotheses and inferences along with the building of proper models to explain their observations. The pupil should be learning the importance of accurate data interpretations.

If the teacher wishes to cover more subject material (e.g. galaxies, expanding universe, theories on the origin of the universe), he may very easily do so. However, pupil interest may be dulled by too many astronomical facts and figures.

This unit provides an excellent occasion for pupils to show their creativity and imagination in terms of model building and formulating hypotheses. The teacher should encourage the development of these skills whenever possible.

CONCEPT: The earth and its relationship to the moon, sun, and other stars provides a framework for determining apparent and real motions.

ACTIVITY 1. Determination of the Observer's Latitude

Introduction

The observer's latitude on earth is defined by determining the angle of elevation (altitude) of the North Star (Polaris). The activity can also be developed to suggest that the earth has a spheroid shape.

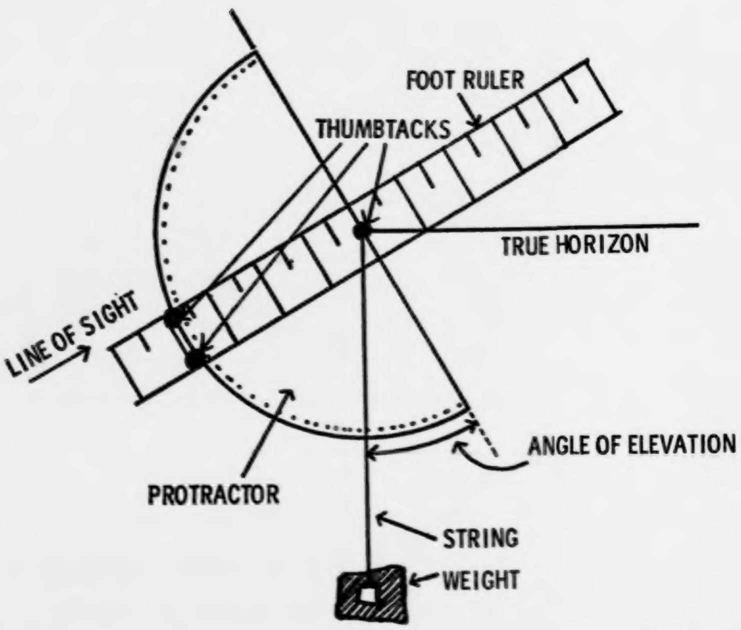
Materials

- 1-foot wooden rule (or a piece of wood of similar length)
- 6-inch protractor
- 3 thumbtacks
- 1 piece of string or thread
- 1 small weight (a nut, key, or sinker)

Procedure

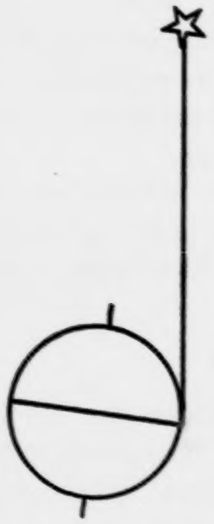
Ask the pupils to make the device for measuring the altitude of the North Star. (See diagram.)

This device should be made in class. Check the device by measuring the angle between the ruler and a table top with another protractor. Note the angle mark the string is pointing toward. The two angles must be the same. (Note: Make sure the pupils can locate the North Star.) Using the angle of elevation device, direct the pupils to determine the angle of elevation of the North Star (Polaris) as a night-time activity. The teacher may record the pupil readings on the chalkboard.



Are all the readings essentially the same? If so, why? If not, why not? Have the pupils suggest the significance of their readings in terms of an earth relationship. What would be the angle of elevation if the observer were standing at the North Pole? At the equator? Could the pupils use the North Star for location purposes if they were in the Southern Hemisphere?

Have the pupils draw a model which shows the angle of elevation to the North Star at the North Pole, their observing location, and a location on the equator. The pupil will realize the model must be based on a sphere which should illustrate proof that the earth has a spheroid shape.



If the earth were flat, would the observer still obtain the same angle determinations to the North Star? Have the pupils check the latitude at their location using a map, globe, or any other means. This will check their accuracy.

The teacher might suggest that one pupil or a group of pupils might determine the longitude of their position and report on the natural relationship between these lines and the earth.

The pupils have now located their position on earth. They should next aim their sights toward observations of the universe in terms of this location.

ACTIVITY 2. The Shape of the Orbital Path of the Earth

Introduction

It is assumed that pupils are aware that the earth moves (revolves) around the sun. This activity directs the pupils' attention to the elliptical shape of the earth's orbit and the sun's location at a focus of the ellipse.

Materials

piece of cardboard about 8½ inches x 11 inches
two thumbtacks
piece of string or thread about 7 inches long
pencil
ruler

Procedure

This activity can best be carried out individually if sufficient materials are available.

Insert the two thumbtacks approximately 2 1/4 to 2 1/2 inches apart in the center of the piece of cardboard. Tie the ends of the string or thread together, and place around the thumbtacks. Place your pencil inside the loop of string, and keeping the string taut against the thumbtacks, draw the ellipse. Remember to keep the string taut. The resultant shape is similar to the elliptical orbital path of the earth around the sun.

Point out to the pupils that the thumbtacks are the foci of the ellipse. When referring to the elliptical motion of the planets around the sun, one focus is the center of the sun.

Have the pupils collect data and formulate hypotheses concerning this model. If the sun is at one of the foci of the ellipse, how close is the sun to the earth at the closest point? What is the distance at the furthest separation of the sun and the earth? Is this the reason for the seasons of the earth? How long does it take the earth to orbit around the sun? Does the earth move faster in certain phases of the elliptical orbit than others? A discussion of these points will logically lead into the next activity, which deals with earth motion in its elliptical path.

ACTIVITY 3. The Earth in Orbit

Introduction

This activity introduces the sun-earth relationships (in terms of gravity) as the earth orbits the sun.

Materials

- small rubber ball (3-5 inches in diameter) or any weight that can be attached to the string
- strong string (about 50 inches in length)

Procedure

This activity might best be completed as a demonstration or in groups of five. Tie the string securely to the ball or weight. Standing in an unobstructed area, twirl the ball in a circle above the head. First hold the string 12 inches from the ball. Count the number of orbits per minute. Repeat the exercise holding the string at 24, 36, and 48 inches from the ball. Record the number of orbits per minute for each new distance.

What happens to the number of orbits per minute as the ball and the person come closer together? What happens at 24, 36, and 48 inches? How can this model situation be applied to the real sun-earth relationship? Use the elliptical model from a previous activity (Activity 2) to help your explanation.

Have the pupils formulate hypotheses to explain why the earth moves more rapidly as it gets closer in its orbital path to the sun?

ACTIVITY 4. Earth, Moon, Sun Relationships: The Phases of the Moon

Introduction

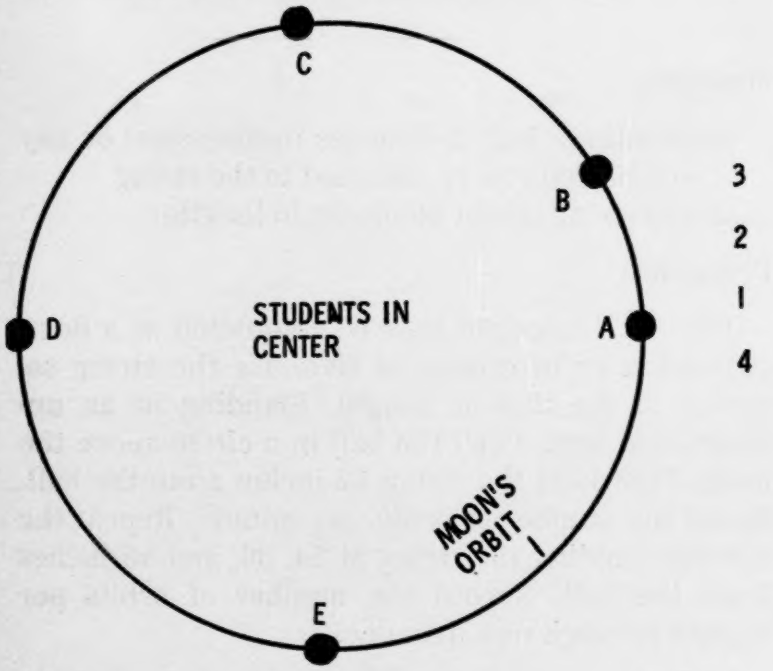
The earth's satellite goes through a series of phases as it revolves around the earth. This activity presents an earth, moon, sun relationship which should clarify the real motions involved in this situation of the Astro-System.

Materials

- light source
- globe, basketball, or some other similar sized ball

Procedure

Place the light source at the front of the darkened room. Use the globe or basketball to represent the moon. The light will represent the sun, and the pupils in the center will be on earth looking at the moon. A group of four or five pupils in the center works best for proper observations. Instruct the pupils to record their observations in terms of the earth, moon, and sun positions.



With the light in position 1, hold the globe or ball between the pupils and the "sun" as in A, Figure 1. What phase of the moon is represented? (New Moon.) Move the ball to position B, Figure 1, and move the light to position 2. Have pupils record and draw diagrams if possible of the earth, moon, and sun relationships.

Move the "moon" around in its orbit to position C, Figure 1, and move the light to position 3. What phase is presented? Move the light to position 1 and the "moon" to position D. Observe and record. (Full Moon.)

Adjust ball to position E and place light at position 4. Observe and record. (Note the light is moved to simulate parallel rays from the sun.)

Discuss what would happen if the moon, during its full moon phase, passed into the earth's shadow. (Lunar Eclipse.) What would result if the moon blotted out the light from the sun? (Solar Eclipse.) The teacher might want to extend this activity by demonstrating lunar and solar eclipses using the setup for the phases of the moon.

ACTIVITY 5. The Apparent Motion of Objects in Night Sky

Introduction

The purpose of this activity is to make observations of the night sky, thus revealing the apparent movement of the stars. Based on the accumulative data, the pupil will develop a model to explain his data in terms of real earth and star motions.

Materials

angle of elevation device (See Activity 1)

Procedure

Direct the pupils to make the measuring device if they have not already done so. The directions are given in Activity 1 of this concept development.

Observations

Measure the angle of evaluation of the North Star, an eastern star, western star, southern star, and a star overhead. Take three readings of each star at one-hour intervals. Record your angles and the time in a data table.

(Suggested data table)

Time	North Star	Eastern Star	Western Star	Southern Star	Overhead Star

(Note: The teacher will have to make sure that everyone has a knowledge of the location of the North Star.)

Based on the data, have pupils develop hypotheses and a model which will explain the data.

The most important aspect of this activity is the pupil model, developed to explain the observations. Ask the pupils what happens to the stars in each of the directions. The teacher should put a summary of the data on the chalkboard.

The stars appear to move from east to west; the North Star does not appear to move at all.

Three possible models, based on pupil observations, include:

1. The earth is standing still, and stars are revolving around earth.
2. Stars are standing still, and the earth is rotating.
3. Both stars and the earth are rotating.

Pupils should become acquainted with apparent motion and the formulating of hypothesis and models to explain observations.

Does the earth rotate and the stars stand still? Do stars move and the earth stand still? Do both move? These questions should be answered by the pupils if possible.

ACTIVITY 6. Photographing the Tracks of Polar Stars

Introduction

By the use of an instrument—the camera— the apparent movement of stars can be observed. This activity provides an accurate record of the star relationships and should cause the development of models to explain the pupil observations.

Materials

camera (one that can be set for a time exposure)
tripod (or some other object for propping up camera)

Procedure

This might be done as a class project; however, several pupils might wish to try the activity on their own. The best results will be obtained in the absence of any surrounding light. Therefore, a clear, moonless night would be the best time.

Set up the camera on a tripod or other suitable support so that it will point toward the North Star (Polaris). When the camera is in position, carefully open the shutter without moving the camera. Expose for at least one hour. However, the longer the exposure the longer the star trails. When exposure is completed, carefully close the shutter. (Note: Do not move the camera during the exposure, and keep any lights away.)

The discussion of the photograph thus obtained should center on the meaning of the star trails. Have the pupils develop mental models to explain the photograph. (Note: Star trails are caused by rotation of the earth.)

Ask pupils to explain the shape of the trails. Where is the North Star (Polaris) in the photo and why does it not move? Are the stars moving and the earth standing still? Is the earth moving and the stars standing still? Are the earth and stars both moving but one faster than the other?

CONCEPT: The earth-sun relationship, the tilt of the earth's axis, and the parallel nature of the earth's axis are the determiners of the earth's seasonal changes.

ACTIVITY 1. The Causes of the Seasons

Introduction

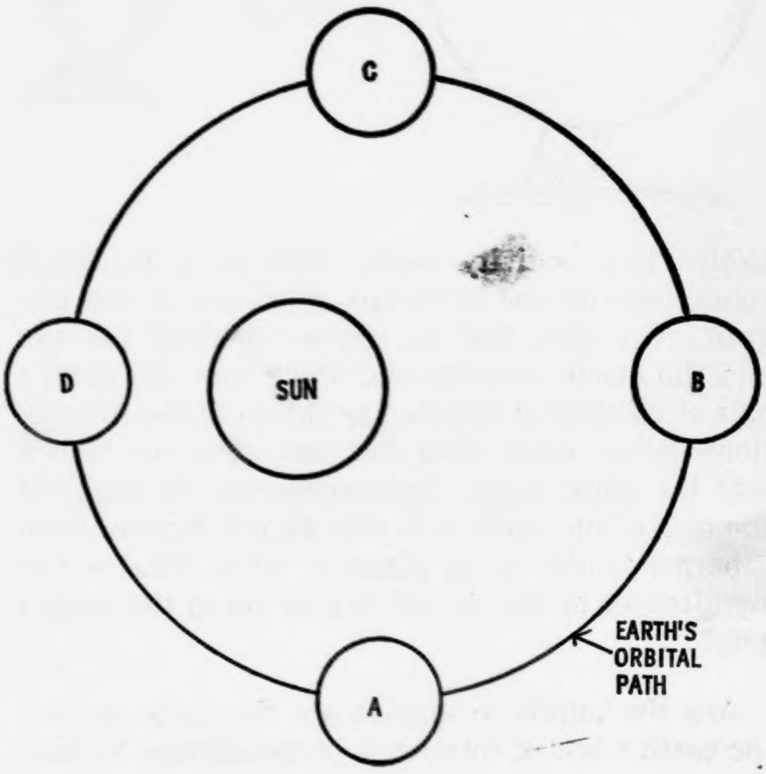
This activity introduces the three fundamental reasons for seasons: (1) the revolution of the earth around the sun, (2) the inclination of the earth's axis, and (3) the parallelism of the earth's axis. The significance of the varying nature of angle of the sun's rays is emphasized.

Materials

world globe
light
flashlight
piece of cardboard about 8 1/2 inches x 11 inches
two thumbtacks
piece of string about 7 inches long
pencil
ruler

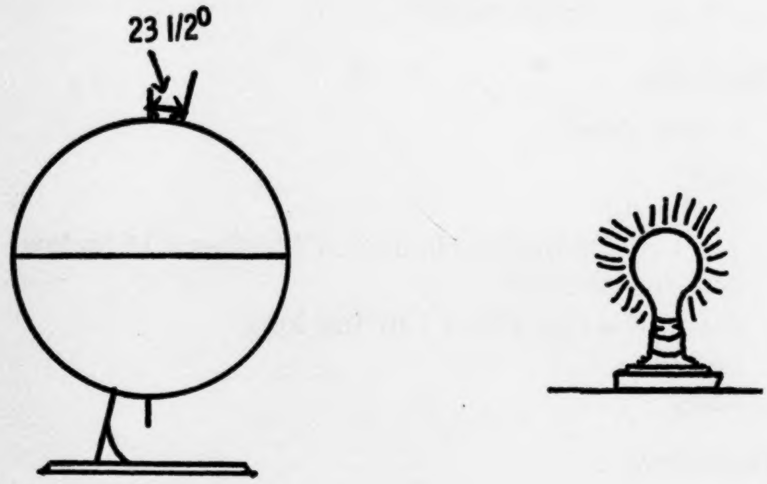
Procedure

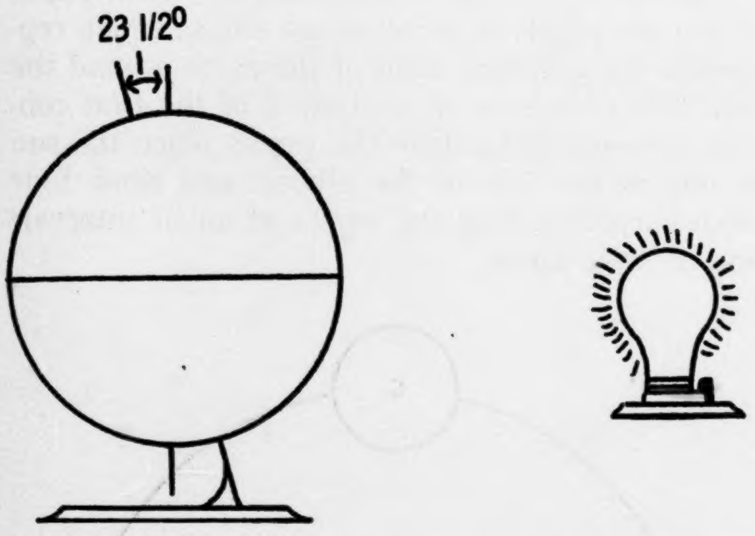
This section should be completed by each pupil. Direct the pupils to construct an ellipse which represents the elliptical orbit of the earth around the sun. (See directions in Activity 2 of the first concept development.) Have the pupils place the sun at one of the foci of the ellipse, and draw four circles (representing the earth) at equal intervals around the ellipse.



The diagram now represents the initial construction to illustrate the reasons for the seasons. Suggest that the pupils develop a model which might explain the seasons based on their limited data and observations. (Note: In the diagram, many will wish to label the earth's postion D as representing summer because of close position to sun.)

Four pupils per group will work satisfactorily for the next section.



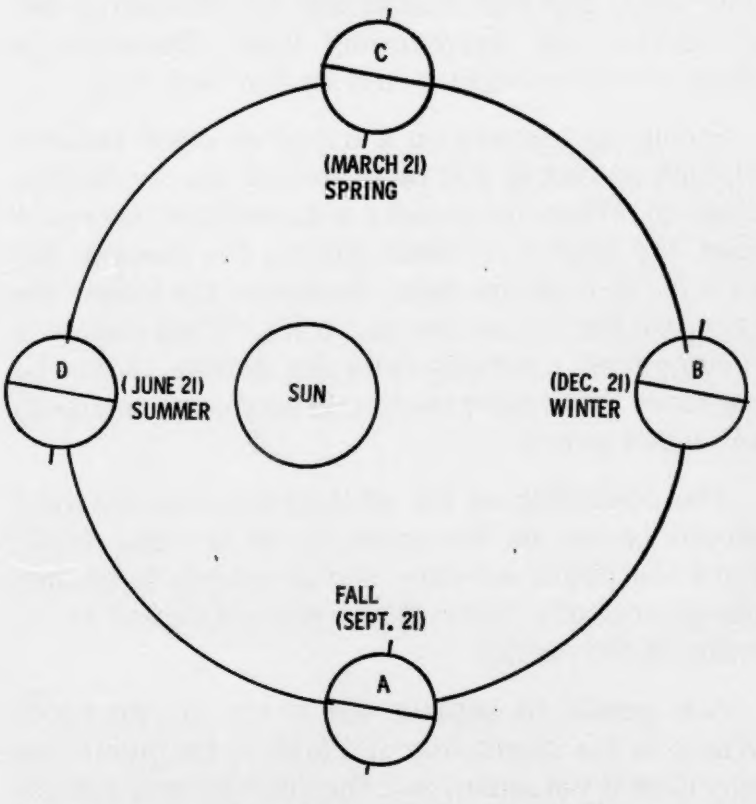


(Note: This activity works best in a darkened room.) Set up the materials as shown in the diagram. The light and the globe represent the sun and the earth, respectively. Make sure the earth's axis of rotation is oriented as shown in the illustrations. What object does this axis point to? Notice that the globe leans. This represents the angle of the axis of the earth as it tilts 23 1/2 degrees from a perpendicular to its plane of orbit. What is the significance of this 23 1/2 degree tilt of the earth's axis?

Ask the pupils to manipulate the globe so that the earth's axis of rotation is perpendicular to floor or table. Move the globe around the light (sun) in an elliptical path. Discuss pupil observations. Does each part of the globe receive the same amount of light during the entire revolution around the light? If this were a true model, would there be any seasons?

The teacher must develop the significance of the tilt of the earth's axis. Suggest that the pupils set the globe position so that the 23 1/2 degree tilt of the axis is present. Now move the globe in an elliptical path around the light. Does each part of the globe receive the same amount of light during the entire revolution? Why must the earth's axis of rotation always point in the same direction (North Star)? Is the axis of the earth always parallel as it moves around the sun? When might it be summer in the Northern Hemisphere (when the North Pole is pointing more toward the sun)? When might summer occur in the Southern Hemisphere (when the South Pole points toward the sun)?

Ask the pupils to complete their diagrams started in the first part. Draw in the earth's axis so that it tilts at 23 1/2 degrees to the plane of the earth's orbit. Draw in the equator in each earth diagram.



Now have the pupils complete the model by labeling each position of the earth as summer, winter, fall, and spring. (Note: Again, pupils will want to label earth position D as summer because of close position to sun. This is incorrect. The earth-sun distance at Point D is about 3,000,000 miles closer than at Point B. However, suggest that this is an insignificant distance in terms of 93,000,000 miles. Stress the tilt of the earth's axis.)

Discuss the three fundamental reasons for the seasons as so developed. Emphasize the revolution around the sun, the inclination of the axis, and the parallelism of the axis (always points in the same direction as it revolves around the sun).

The constant position of the earth's axis (parallelism of the axis) causes the angle of the sun's rays to vary as the earth revolves around the sun. The important fact is that vertical rays of the sun concentrate the heat over a smaller area compared with rays which strike at an angle.

Demonstrate the area covered by the light rays when a flashlight is pointed directly at the chalkboard and when pointed at an angle. In a follow-up discussion, stress the amount of area covered in each case. Why would less heat be produced in the area produced by the indirect rays? What is the relationship between the directness of the sun's rays and the seasons?

Using the globe and a flashlight, have the pupils move the globe in a counterclockwise direction around the light source. Simulate the model as illustrated by their diagram. At which position, A, B, C, or D, would the most direct rays be striking the North American continent? What season would such a position indicate? (Note: The sun's rays are vertical 23 1/2 degrees north of the equator during summer.)

At which position, A, B, C, or D, would the least direct rays be striking the North American continent? What season would be represented by this position? (Note: The sun's rays are vertical 23 1/2 degrees south of the equator during winter.)

The concluding discussion of this section should emphasize the relationships between the tilt of the earth's axis, the nature of the angle of the sun's rays, and the amount of heat produced.

CONCEPT: Nearly everything we know about stars and other objects in the sky is learned by studying the light they send us.

ACTIVITY 1. How Far is a Light-Year?

Introduction

Distances in space are so large that usual standardized measures become useless. Therefore, astronomers use the light-year as a unit of distance. This activity exposes the pupil to the almost unbelievable distance in one light-year and should broaden pupil thoughts concerning distances to stars.

Materials

pencil
paper

Procedure

Discuss the meaning of a light-year. A light-year is the distance light travels in one year at the speed of 186,000 miles per second.

Have the pupils calculate a light year in terms of the mile unit.

Alpha Centauri is the closest star (other than our own sun) to earth. It is about four light-years away. Calculate the earth-Alpha Centauri distance.

Can the pupils imagine distances of this magnitude? Hopefully, the pupil may gain some appreciation of the vastness of space.

The teacher may present other light-year distances to various stars if it is desirable. Suggest that some of the light we are observing now left the very distant stars when dinosaurs were roaming the earth.

ACTIVITY 2. How Big Is Our Sun?

Introduction

The enormous size of the sun is introduced to the pupils by having them observe, measure, and then make mathematical calculations. This activity illustrates another method of making astronomical observations and the utilization of the accumulated data to establish relationships and dimensions by an indirect procedure.

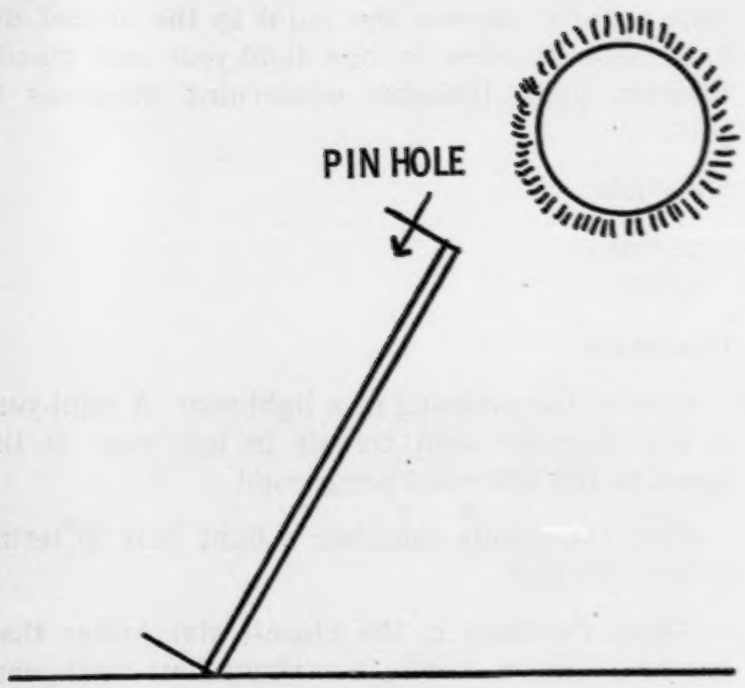
Materials

meter stick
two 4" x 6" unlined white cards
two thumbtacks
metric ruler (graduated in millimeters)

Procedure

Have the pupils work in groups of two.

This activity must be completed on a day when the sun is shining. First make a pinhole with a thumbtack or a pin in the center of one of the cards. Attach the cards to each end of the meter stick with the thumbtacks.



Have one member of the group aim the meter stick at the sun (**CAUTION:** Remind the pupils **not** to look at the sun). There should be an image of the sun formed on the other card. Have one pupil measure the diameter of the image. Record the measurement. Pupils should reverse positions. Follow a similar procedure to determine the diameter of the sun's image; again record and average the two measurements.

How can the diameter of the sun be determined? Suggest a simple ratio problem to the pupils.

$$\frac{\text{image distance}}{\text{object distance}} = \frac{\text{image size}}{\text{object size}}$$

The object distance is 150,000,000,000 meters. We are solving for the object size. The image size and image distance are determined by measurements off the apparatus. (Actual diameter of the sun is about 1,400,000,000 meters or 1,400,000 km.)

Discuss the activity in terms of the size of the sun compared to the earth and other astro-objects. Is the distance to the sun always the same?

ACTIVITY 3. The Composition of Stars

Introduction

Use of the spectroscope as a tool for identification of the elements and compounds present in stars is the fundamental purpose of this activity. Each element in the form of a hot gas produces a different pattern on the spectrum. Therefore, by studying the light produced by a star, scientists can determine its composites.

Materials

chemicals (powdered)
  sodium chloride (yellow)
  copper sulfate (blue-green)
  strontium chloride (crimson)
  calcium carbonate (reddish)
spectroscope
bunsen burner or alcohol lamp
stainless steel teaspoon
colored pencils

Procedure

Part I—Aim the spectroscope toward the sky. (**CAUTION:** Do not look directly at the sun.) Ask pupils to draw what they see. A continuous spectrum should be produced and drawn by the pupils.

Suggest that someone in the class use the spectroscope to observe moonlight. Have him draw the spectrum. (Note: Moonlight will not produce the spectrum because it is reflected light and not direct light from source of glowing gases.)

Part II—This series of tests illustrates that each element produces its own particular flame when heated.

Using the sodium chloride, copper culfate, strontium chloride, and copper sulfate, follow the same basic procedure for each. (**CAUTION:** Pupils must be careful when handling chemicals in the flame.)

1. Light burner.
2. Wet stainless steel spoon with water and insert into powdered chemicals. (Powder should stick to spoon.)
3. Hold chemical in flame.
4. Examine color of the flame.

Record the flame color produced by each substance. (Sodium will produce yellow flame; copper will produce green-blue flame; strontium will produce a crimson flame; calcium will produce a reddish flame.)

Part III—Use the same procedure and chemicals as used in Part II, but look at the colored flame produced with the spectroscope.

Aim spectroscope at the colored flame. (Put within a few inches of flame but be careful not to burn the spectroscope.) Have pupils draw what they see in color. (Example: Sodium will produce two yellow lines.) Compare their drawings with that of the sun's spectrum. What is the relationship between the two yellow lines of sodium spectrum to that of sun's spectrum? (Each substance has its own spectrum. The color of the lines in each spectrum, and their positions are properties of that substance only.)

What does all this have to do with the composition of the stars? Through library research, have pupils learn about the composition of the sun as well as other stars.

The pupil, by performing this activity, should understand that the composition of a star can be determined by the light it produces.

ACTIVITY 4. The Approximate Temperature of Stars and Their Color

Introduction

The color of a star gives an indication of the approximate temperature of the hot gases making up the body. This activity, in a simplified manner, is designed to give the pupil a relationship between color and relative temperature.

Materials

hot plate, bunsen burner, alcohol lamp, candle
tongs (or any instrument for holding substances in flame)
paper clips
magnesium ribbon
iron wire
copper wire

Procedure

This activity may be completed in groups of four or five pupils each or, because of the risk of working with the bunsen burner, may be done as a demonstration.

First, have pupils observe and record the colors of the flame produced by the bunsen burner, alcohol lamp, a candle, or the coil in a hot plate. Discuss the difference in the colors of the flames and difference within each flame. Which flame has the highest temperature? Which part of the flame is the hottest? Did the coil of the hot plate change color when it became hotter? Have pupils make inferences based on their observations and formulate hypotheses concerning the relationship between color and temperature.

Next, suggest that the pupils heat some of the materials (paper clips, wire, ribbon, etc.) and observe any change in color of the objects as they become hotter. As the paper clip or other object grows hotter, it should grow red to orange in color and possibly white hot, if the heat source is intense enough. The magnesium ribbon becomes white hot. From their observations, which color represents the higher temperature or hottest condition of the object?

Are stars of different colors? Our sun is a yellow star. What is the relationship of its surface temperature to Antares which has a red color?

Discuss the relationship of the spectrum (as observed in Activity 3) and the temperature of the stars. In the spectrum of a reddish star, which portion of the spectrum should be the brighter? If a star has a blue-white color, which part of the spectrum will be more intense? A star which has a yellow color (our sun) has a fairly even spectrum over the entire range.

The following chart lists the color and approximate surface temperatures. The teacher might want to use this data to relate absolute temperatures to color.

Color	Surface Temperature
blue-white	greater than 36,000° F
yellow-white	13,500° F
yellow	10,000° F
orange	7,500° F
red	5,500° F

ACTIVITY 5. How is the Great Heat and the Light of the Stars Produced?

Introduction

This activity is designed to acquaint the pupils with nuclear energy. This subject is difficult to investigate within the classroom setting, so a library research project on the topic is suggested.

Procedure

Suggest that the pupils write a short paper which might answer or suggest answers on the following points:

1. What is the nature of a nuclear reaction?
2. What forms of energy are produced by a nuclear reaction?
3. What is the fuel necessary for a nuclear reaction on our sun?
4. How long will a star's fuel supply usually last?
5. What happens to the star's fuel when it undergoes a nuclear reaction?

6. Do stars change into matter or energy or both?
7. How much longer will our sun last?

When writing, the pupils should be cognizant of the inferences, hypotheses, and theories that have been developed to explain some of the phases of the nuclear reaction on the sun and the effects of this reaction. These should be incorporated into their paper.

After the completion of this activity, discuss the findings of the pupils. Most of the suggested topics should precipitate good discussions.

EVALUATION

The recall of facts and figures concerning the Astro-System is not considered an important evaluative technique. The examinations should emphasize concept understanding and pupil ability to implement the basic skills of hypotheses formulation, model-building, and data interpretation.

The teacher might construct an earth-moon-sun model, illustrating a phase of the moon, and have the pupils formulate hypotheses concerning the model. A model illustrating one particular season in terms of earth-sun relationships could be set up. Again, have the pupils formulate hypotheses and interpret any data dealing with the model. Any number of models might be developed for evaluative purposes. Have the pupil relate nuclear energy, temperature, and color of stars. How do we know the composition of the stars?

All of the evaluation techniques might best be accomplished in a laboratory practical examination.

Suggested Overlays

1. Revolution and Rotation of Earth - and Moon
2. Phases of the Moon
3. Seasons of the Year
4. Eclipse of the Moon and Sun
5. Sun's Continuous Spectrum
6. Emission-line Spectra for Sodium

GRADE SIX

EQUILIBRIUM SYSTEMS

UNDERSTANDING THE concept of equilibrium is basic to the understanding of many naturally-occurring systems we meet in our everyday lives. Naturally-occurring systems are not usually closed systems and hence cannot be considered to be at equilibrium. However, the ideas involved in systems approaching equilibrium are very important in understanding such things as the chemistry of the blood, the deposition of salt in lake beds, and the formation of stalactites in caves.

Unfortunately the word *equilibrium* may frighten many teachers into omitting this concept. A serious effort has been made to present certain aspects of equilibrium which are within the grasp of the sixth grade pupil. Emphasis will be placed on naturally-occurring systems wherever possible. The pupil will be encouraged to *design experiments* and *control variables* wherever appropriate. (Reminder: State law requires the use of protective eye devices when handling hot liquids, acids, caustic chemicals, or solids when risk is involved.)

Unit Goals

Upon completion of this unit the pupil should:

1. Be able to give an operational definition of equilibrium.
2. Understand the meaning of the following words: concentration, saturated and supersaturated solutions, and ions.
3. Know the factors which affect equilibrium systems.
4. Recognize equilibrium has not been found to exist in nature because there are apparently no truly closed systems in nature.
5. Know that many natural phenomena can be understood in terms of systems approaching the state of equilibrium.

Unit Development

The first concept attempts to present equilibrium as a balance between opposing forces. Activity 1 emphasizes the balancing of forces of weight as an example of physical equilibrium. Activity 2 presents a phase change equilibrium. Emphasize the crystal growth in this activity. Activity 3 deals with still a third kind of equilibrium, thermal equilibrium.

The second concept deals with open and closed systems. A system is closed when the matter in it is constant, i.e., when it is not entering or leaving the system. A system is open when matter is entering and leaving the system.

The final concept deals with those things which affect equilibrium. Temperature and concentration are presented as the two main changes which affect equilibrium.

CONCEPT: Equilibrium exists where there is a balance between opposing forces.

ACTIVITY 1. Balancing Equal Forces

Introduction

This activity deals with the balancing forces. The concept of forces has been dealt with in a fifth grade unit, "Force Systems." The introduction of balanced forces here is intended to lead naturally to chemical equilibria and phase equilibria.

Materials

5 meter sticks

5 spring scales (calibrated in grams)

5 meter stick clamps

5—100-gram weights (any mass will do but it must be less than maximum measure of the spring scale)

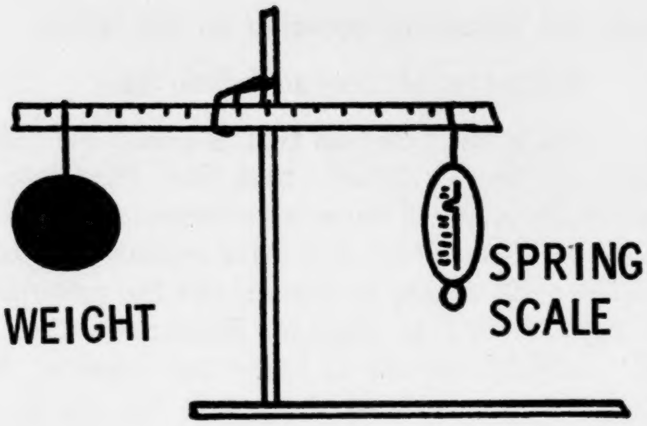
string

Procedure

Give each group a meter stick, meter stick clamp, a 100-gram weight, and a spring scale calibrated in grams.

Direct each group to suspend the stick and balance it at its center. Have each group select a point on one side of the balance point and attach a 100-gram weight. Have each group use the spring scale to demonstrate the force necessary to maintain the meter stick level as illustrated.

Have the group measure the downward force necessary to balance the meter stick at different points. Tell them to record their data. Ask what conclusions they could draw from their data. Lead them to conclude that when the spring scale and the gram weight are equidistant from the clamp, the reading on their spring balance is the same as the 100-gram weight. Ask why this is true. Help them to understand that when equal forces are applied the system is in balance or in equilibrium. They should also note that a greater force is required closer to the clamp and a lesser force farther away from the clamp than the weight. In other words, the force exerted on the system is related to the force applied and its distance from the meter stick clamp.



ACTIVITY 2. Sublimation equilibrium

Introduction

In the previous system physical equilibrium was investigated. In this activity the phase equilibrium between a solid and its gas will be examined. This activity will also provide the class with opportunity to observe two phenomena. One of these will be the process of sublimation in which a solid changes into a gas. The other phenomena is that of a colored gas. Do not draw attention to these two observations unless, by the end of the activity and discussion, they have not been mentioned by the class.

Materials

iodine crystals

10—250 ml. erlenmeyer flasks and stoppers

5—400 ml. hot water beakers

Procedure

Divide the class into five groups and give each a flask, stopper, and a small amount (about 1 gram) of solid iodine crystals. Direct them to place the crystals in a flask. Stopper the flask tightly, then place the flask on or against a white background next to another stoppered flask which contains only air. Ask the pupils to make their observations for a 10 to 20-minute period. Ask them to make two or three additional observations at appropriate times during the day.

In the next class meeting, ask them to complete their observations. The contents will gradually change color. For some the intent color may be so faint that they will not see it. The white background and the control will help. Ask them to describe their observations. Eventually the color will become constant and will not change. Ask why the area above the solid is colored. Lead them to conclude that it is filled with a gas, which results from the sublimation process involving iodine.

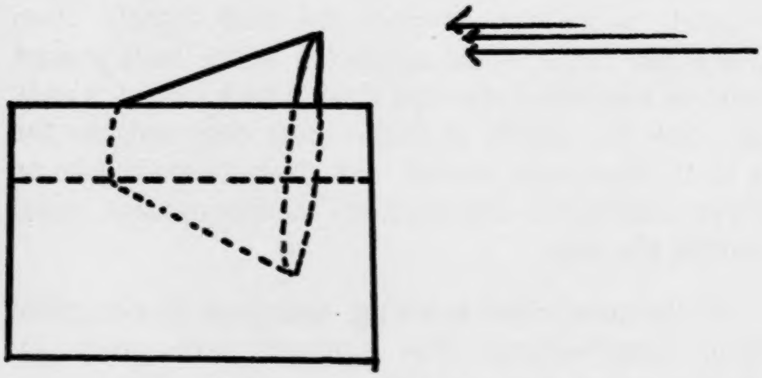
Write the following equation on the board:

Iodine (solid) goes to Iodine (gas)

State: "This is the reaction that is occurring." Ask if there is any evidence that the changing of states has stopped. If there is no response, lead the class to the observation that after a while the color above the solid ceases to change and the amount of solid appears not to change. Emphasize the apparent constant nature of these two aspects. Ask what this means. Unless the pupils can explain it this way, help them to conclude that a constant color means a constant amount of gas present. Ask what might cause this.

One suggestion will be that no more of the solid can change into a gas. Indicate that this is a logical conclusion, considering what they know at the present. Ask if anyone else can suggest another way this constancy of gas could be maintained. If there are no suggestions, mention that each basketball team has five players on the floor at all times and a constant number of "subs" on the bench. Ask how this analogy can help explain the constant color in the flask. Lead the class to realize that there is a constant number of boys on the floor because when one goes in, another comes out. There are two reactions; one is boys going from bench to floor and the other is boys going from floor to bench.

A similar situation exists in the iodine case. The iodine is undergoing two reactions. One is the sublimation reaction, and the other is the condensation reaction. Tell the class that they can observe this condensation by placing the flask in a beaker with hot water as indicated below:



A slight breeze blowing over the surface of the flask from a fan or an open window will cool the surface of the flask, and small crystals of iodine will form on the surface. Give each group a magnifying glass and tell each pupil to draw a typical crystal and determine how the different crystals are alike and how they are different. The crystals will appear as long and plate-like diamond-shaped objects. Often crystals will grow together and will appear as various combinations and orientations of crystals.

ACTIVITY 3. Thermal Equilibrium

Introduction

This activity presents the idea of thermal equilibrium as another example of the balance of two opposing forces. In this case the gaining of heat and the loss of heat will be stressed. Cold will be discussed in terms of low heat level.

Materials

5—50 ml. pyrex erlenmeyers
10 thermometers (Centigrade)
50 ml. cooking oil
50 ml. rubbing alcohol
50 ml. saturated salt solution
50 ml. saturated sugar solution
ice
5—500 ml. beakers
burners
ring stand
ring clamp
sodium chloride (NaCl)

Prepare saturated solutions by mixing more salt or sugar in 100 ml. distilled water than will dissolve. Stir vigorously and let stand two to three hours. Divide the class into five groups. Be sure that the following liquids have been sitting in a part of the room which has a fairly constant temperature for two or three hours or longer:

1. cooking oil
2. water
3. salt solution
4. rubbing alcohol
5. sugar solution

The liquids should be in 50 ml. erlenmeyer flasks with a thermometer inserted in each stopper. Do not allow the class to examine these flasks to determine their temperature.

Ask the class which liquid they would expect to be at the highest temperature and which at the lowest. After they have made their estimates, give each group one of the liquids and have them read the temperature. Record the reported temperatures on the blackboard and ask why they all appear the same? Have someone determine the temperature of the room where the flasks were standing.

Direct the class to place the different flasks in water of about 50 degree temperature. Ask them to observe what happens. Then have them put the liquids in the same place and again let stand until the next day. Determine the results and discuss in terms of the heat loss of the liquids. Place the liquids in a cold ice-salt mixture and let them come to the lowest possible temperature. Tell them to remove and let stand overnight. Discuss their results in terms of the heat flow. (Heat flows out of the liquid into the ice-salt mixture. Then, on standing, heat flows into the liquid from the surrounding air.)

Discuss all the observations in this experiment. Attempt to get the pupil to conclude that the temperature of a body tends to become that of its surroundings. Ask what happens when the temperature of a body gets to that temperature. Lead the class to conclude that it does not change. Tell them that when this is true it can be said that the body has thermal equilibrium (thermal means temperature).

Remind the class that, in nature, true thermal equilibrium is probably never reached because of constant fluctuations in temperature. However, this activity should help them grasp the idea that systems with unequal temperatures tend to reach equal temperatures if enough time elapses.

Ask the class to look up the word *magma* in an earth science or geology book and relate the formation of rock from magma to this experiment.

CONCEPT: Systems which appear changeless are actually changing.

ACTIVITY 1. An open and closed solution

Introduction

In this activity the class will prepare two solutions, one for a closed system and one for an open system. They will observe the changes that occur. This activity will last several days.

Materials

1—1,000 ml. beaker

salt (sodium chloride, NaCl)

burner

3—500 ml. beakers

2 petri dishes

large ring clamp and ring stand

Procedure

Divide the class into four or five groups and direct each group to weigh out 60 grams salt and place it in 100 ml. of distilled water. Do not stir. Have them record their observation.

Direct each group to weigh out 25 grams of salt and place it in 100 ml. of water. Ask the groups to compare the results. Dissolving occurs in both cases, but in one case the solid dissolves entirely and in the other case some of the solid remains. Ask why. The class will probably wish to discuss this in terms of the solubilities involved. In one case, there is too much solid to dissolve.

Attempt to focus attention on the dissolving reaction:

$$\text{NaCl (solid)} \longleftrightarrow \text{NaCl (aqueous)}$$

(Aqueous is a word used to indicate that the solid is dissolved in water.) In the previous concept the opposing forces involved in equilibrium situations were discussed. Ask the class how they could be used to explain the fact that in one case the solid dissolves and in another case it does not. The pupils may be puzzled at this point.

Discuss the iodine situation. Remind the class that at the point called equilibrium they observed a constant color and inferred a constant amount of the gas. It follows that there was a constant amount of solid. Remind the class that it was postulated that this would result when the rate of sublimation equalled the rate of condensation. There were these elements of constancy about the iodine situation.

In the case of the salt water solution, first the element of constancy is not there; i.e., the solid is dissolving. If there are two opposing reactions, they must not be occurring at the same rate. The word *dissolving* will be used for the forward reaction and the word *deposition* for the reverse reaction. The fact that the solid is dissolving could be explained in terms of forward reaction going faster than the reverse reaction.

Let both solutions stand overnight and observe the next day. Ask how the rates of the opposing reactions can explain the results. In the case where solid remains, the two reactions are canceling each other. In the case where everything dissolves, the forward reaction goes so far as to prevent the reverse reaction from occurring.

Emphasize the fact that these systems appear changeless.

Direct the groups to pour off the liquid from the solid, divide it into two 50 ml. portions, and place the portions in two petri dishes. Cover one of the dishes. Leave the other dish open. Let stand for two or three days until change in one of them is observed. Allow the open portion to sit until dry. Ask the groups to describe their results in terms of forward and reverse reactions.

Ask whether an ocean or lake is an open or closed system. What evidences could be pointed out?

CONCEPT: Concentration and energy changes temporarily upset the equilibrium, favoring one of the two directions of the equilibrium reactions.

ACTIVITY 1. Temperature affection No.^{2} $\longrightarrow$ $\longleftarrow$ N^{2}0^4 equilibrium

Introduction

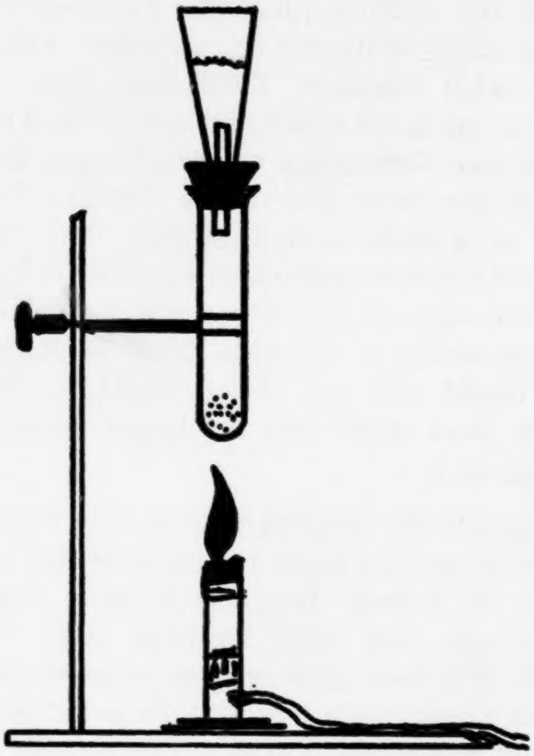
Systems at equilibrium are affected by temperature. In fact, temperature changes upset the equilibrium for a time, but it is re-established at the new temperature.

Materials

- 50 ml. erlenmeyer flasks
- lead nitrate $Pb\ (NO_3)_2$
- ring stand and utility clamp
- large test tube and one whole stopper to fit 6" piece of glass tubing
- 10—400 ml. pyrex beakers
- salt (sodium chloride, $NaCl$)
- ice
- ring clamp
- wire gauze
- 10—250 ml. beakers
- burner
- copper sulfate ($CuSo_4 \bullet 6H_2O$)

Procedure

Generate the NO_2, N_2O_4 mixture by placing 10 grams of $Pb\ (NO_3)_2$ in a large test tube clamped in a vertical position. Place a 1-hole stopper with a piece of glass tubing protruding from the top about 8 to 10 cm. as indicated. Invert a 50 ml. erlenmeyer flask over the glass tube; heat the bottom of the test tube vigorously. The teacher will observe one of the phenomena somewhat unique to this material; that is the process of decrepitation. The heating of the crystals drives the water out of them, and they split apart and jump around a bit like popping corn. Soon a brown gas will form, rise into the glass tube, and go into the inverted erlenmeyer flask. When the flask exhibits a definite yellow-brown color, stop heating the test tube and remove and stopper the flask. *Caution: This should be done in a well-ventilated room. The test tube should not be heated so fast that the brown gas is driven into the air outside the erlenmeyer.*

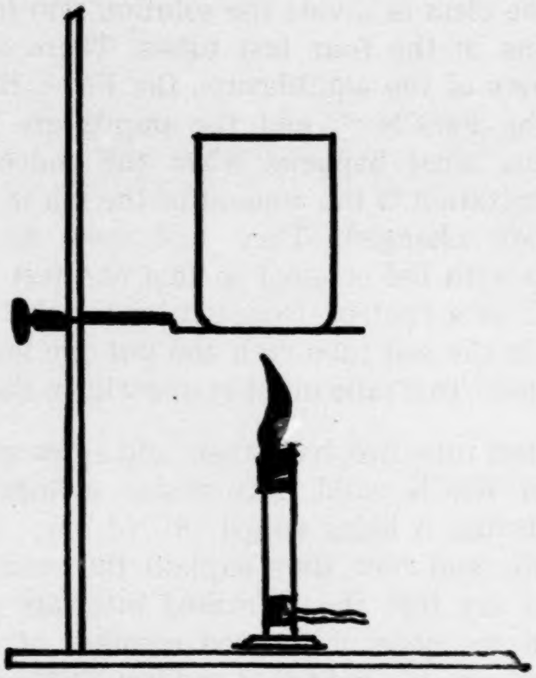


This may be repeated until four or five flasks have been filled. Be sure the flasks are *clean and dry*. They should be prepared just before use, as the gas tends to react with the stopper and turn clear. In this event, it will be necessary to start again.

Divide the class into four or five groups and give each group a flask, two 400 ml. beakers, some ice, salt, and hot water. Have the groups submerge the flasks in hot water and observe the changes which occur. Then direct them to put the flasks into cold water-ice-salt solution and observe the changes. Tell them to reverse the process several times until they are convinced that the reaction is in reality reversible.

Tell the class that this substance consists of two gases mixed with air. One gas is brown and the other is colorless. The colorless one is N_2O_4 and the brown one is NO_2. Ask if they can explain what they observe. When the substance is heated, the brown gas is produced. When cooled, some of the brown gas reacts to form the colorless gas. Ask what is happening when the temperature is not changing. Lead the class to the logical explanation that the rates of the forward and reverse reaction are the same; hence, no apparent change. Tell the class that this is an example of a chemical equilibrium and that it is an example of how equilibria are temperature-dependent. Emphasize that heat is added to get NO_2, and heat is removed to get N_2O_4.

Have each group weigh about 40 grams of copper sulfate ($CuSo_4 \cdot 6H_2O$) and place it in 50 ml. of water. Direct the group to heat the mixture and observe what happens. Note the setup below:



Then direct the pupils to stop the heating. When the beaker is cool enough to touch, cool it in the ice-salt bath and observe what happens.

Ask if this is temperature-dependent. Ask if the dissolving reaction or its reverse, the deposition reaction, requires heat to be added. Ask which requires that heat be removed.

Suggest that in hot springs, the water runs through naturally-occurring minerals and that where it comes from the ground large deposits of limestone are usually found. Ask why this does not occur where regular springs run out of the top of the ground. Lead the class to see that the hot water dissolves more minerals than the cool water and that mineral deposits result when the water is cooled at the surface.

Discuss the water cycle as another example of a system that is temperature-dependent.

ACTIVITY 2. Concentration changes also affect equilibrium situations

Introduction

Concentration changes in one member of an equilibrium reaction cause the equilibrium to be upset. The net result is that the reaction goes on to consume the material added. For example, if we have the following system at equilibrium $AB \leftrightarrows A_2B_2$, adding AB to the system will upset the equilibrium so that more A_2B_2 will result.

Materials

potassium thiocyanate (KSCN)
ferris nitrate ($Fe\ (NO_3)_3\ 9H_2O$)
potassium nitrate (KNO_3)
dibasic sodium hydrogen phosphate (Na_2HPO_4)
distilled water
20 test tubes
10 beakers
5 test tube racks
5 medicine droppers

Procedure

Prepare the following solutions:

1. Place 4 grams of $Fe\ (NO_3)_3$ in 100 ml. of distilled water and stir until dissolved. Label $Fe(NO_3)_3$.
2. Place 1 gram of KSCN in 100 ml. distilled water and stir thoroughly. Measure at 40 ml. and discard the rest, 40 ml. to 160 ml. of distilled water.

Tell the class that in this experiment they will be working with ions. In previous experiments they have worked with atoms and molecules. Ions are very much like atoms and molecules. They are different in that they have a + or — electrical charge. An ion is an atom or a molecule which has an electrical charge. When the formula for an ion is written, its number and kind of atoms involved are written just as for atoms and molecules; but the ions are written with a superscript sign indicating the sign of the charge on the ion. That superscript is followed by a number indicating the magnitude of the charge. The following are some examples of atoms and their corresponding ions:

Atoms		**Ions**	
Name	*Symbol*	*Name*	*Symbol*
Chlorine	Cl	Chloride ion	Cl^{-1}
Potassium	K	Potassium ion	K^{-1}
Iron	Fe	Ferric ion	Fe^{+3}
		Ferrous ion	Fe^{+2}
Copper	Cu	Cupric ion	Cu^{+2}
		Cuperous ion	Cu^{+1}
Mercury	Hg	Mercuric ion	Hg^{+2}
		Mercurous ion	Hg^{+1}
Sodium	Na	Sodium ion	Na^{+1}
Hydrogen	H	Hydrogen ion	H^{+1}
Aluminum	Al	Aluminum ion	Al^{+3}
Silver	Ag	Silver ion	Ag^{+1}
Zinc	Zn	Zinc ion	Zn^{+2}
Sulfur	S	Sulfide	S^{-2}

Tell the class that one kind of ion has not been included on the chart. All ions on the chart consist of just an atom. However, it is possible for groups of atoms which are "tied" together to have a charge. They are ions also. Review the definition of an ion. When more than one atom is combined to form an ion, it is called a radiation. A radical ion is a combination of two or more atoms which have a charge. There are not many common radicals but a few are listed below.

Name	*Symbol*
Ammonium ion	NH_4^{+1}
Thiocyanate ion	SCN^{-}_{1}
Sulfate ion	SO_4^{-2}
Nitrate ion	NO_3^{+1}
Carbonate ion	CO_3^{-2}
Hydroxide ion	OH^{-1}

Have the class make a large wall chart including the names and symbols for both kinds of ions. Place it on the wall so that it may be seen at all times. *Do not* expect the youngsters to memorize these symbols or use this as a basis for evaluation.

Discuss the above list. Ask the class to discuss some unique things about the list such as the charges of the ions and how their names differ from the names of the atoms.

Tell the class that in this experiment K+ ions, SCN- ions, Fe^{+3} ions, and NO_3- ions will be involved.

Direct each group to place 20 ml. of distilled water in a 250 ml. beaker and add 25 ml. of KSCN solution. Have them put five drops of the $Fe\,(NO_3)_3$ solution in the beaker. Ask what differences they note. Tell them that color change is evidence of a chemical reaction and that ions like atoms and molecules undergo chemical reactions.

Ask them what ions are present. If they do not respond, tell them that the $Fe(NO_3)_3$ solution provides Fe^{+3} ions and NO^{3-1} ions while the KSCN solution provides K^{+1} ions and SNC^{-1} ions.

Give each group a few crystals of potassium nitrate (KNO_3) and have them place the nitrate in 25 ml. of water. Tell them that K^{+1} ions are present and that NO^{-1} ions are present. Have them compare this solution with the previous solution and determine which ions are involved in the chemical reaction which resulted in the chemical charge. Since KSCN solution was colorless, the $Fe(NO_3)_3$ solution was yellow, and the KNO_3 solution was colorless, they should conclude that a reaction between the Fe^{+3} ions and SCN^{-1} ions occurred.

Tell the class that the reaction which occurred is:

$$Fe^{+3} + SCN^{-1} \longrightarrow FeSCN^{+2}$$

Yellow colorless red

This is an equilibrium reaction which means that it is a reverse reaction which keeps the color of the solution constant. That reverse reaction is:

$$Fe^{+3} + SCN^{-1} \longleftarrow FeSCN^{+2}$$

Tell the pupils these two equations can be written together:

$$Fe^{+3} + SCN^{-1} \longleftrightarrow FeSCN^{+2}$$

Tell the class to divide the solution into four equal portions in the four test tubes. There are three members of the equilibrium, the Fe^{+3}, the SCN^{-1}, and the $FeSCN^{+2}$; and the pupils are going to examine what happens when the concentrations (concentration is the amount of the ion in the solution) are changed. They will wish to compare results with the original so that one test tube will be left as a control. Direct them to label the four holes in the test tube rack and put one test tube in each hole. Test tube number one will be the control.

To test tube two, have them add a few small crystals of KSCN solid. Ask which member of the equilibrium is being added. (SCN^{-1} ions.) Ask what happens and how they explain the results. They should say that the increased intensity of red is caused by more of the red member of the equilibrium, i.e., the $FeSCN^{+2}$. Adding SCN^{-1} increased $FeSCN^{+2}$. They may counter that Fe^{+3} must be available, and the teacher will wish to remind them that this is true but that Fe^{+3} was present and all of it had not reacted. To the third test tube, have them add two or three drops of $Fe(NO_3)_3$. Ask which member of the equilibrium was added. Ask them why adding more Fe^{+3} changes the color. Lead them to conclude that again more $FeSCN^{+2}$ is produced. Again they may suggest that no SCN^{-1} was added, but the teacher should remind them that it was present in the original solution.

Finally direct each group to add a few crystals of Na_2HPO_4 to the test tube. They will observe that the color disappears. Ask what this means. They should conclude that no $FeSCN^{+2}$ is present. Tell the class that the Na_2HPO_4 reacts with the SCN^{-1} ions and makes it impossible for the Fe^{+3} ions to react with the SCN^{-1}, so the forward reaction, $Fe^{+3} + SCN^{-1} \longrightarrow FeSCN^{+2}$, does not occur. The reverse reaction, $Fe^{+3} + SCN^{-1} \longleftarrow$ does occur. Therefore, the color is removed as the $FeSCN^{+2}$ breaks down. The teacher should lead the class to summarize results and conclusions, developing his own, or using the following outline:

1. Evidence was collected that the red color resulted from the Fe^{+3} and SCN^{-1} ions. The class was told that the following equilibrium reaction existed in solution.

$$\underset{\text{yellow}}{Fe^{+3}} + \underset{\text{colorless}}{SCN^{-1}} \longrightarrow \underset{\text{red}}{FeSCN^{+2}}$$

2. KSCN crystals were added and the red color ascribed to increased $FeSCN^{+2}$ ions. This indicated that SCN^{-1} reacted with Fe^{+3}, which was already present to yield more $FeSCN^{+2}$.
3. $Fe(NO_3)_3$ was added and again more red color was produced. This indicated that Fe^{+3} reacted with SCN^{-1} to yield $FeSCN^{+2}$.
4. Finally Na_2HPO_4 was added and removed SCN^{-1} ions, and the color disappeared.

The class has considered in other activities that equilibrium results when two situations counteract or counterbalance each other. In this case there are two opposing reactions. One we call forward in which $FeSCN^{+2}$ is produced. The other is called reverse where $FeSCN^{+2}$ breaks down. Increased red color has been interpreted as meaning more $FeSCN^{+2}$. If this was true in parts two and three above, the forward reaction must have gone more than the reverse reaction. In part four where the $FeSCN^{+2}$ disappeared, the reverse reaction must have gone to a greater extent.

One can then picture the equilibrium situation as a delicate balance. When the concentration of one of its members is increased (parts two and three) the equilibrium changes so as to consume that member. When one member is removed, the equilibrium shifts so as to produce more of that member. In other words, when a system at equilibrium is subjected to a change, the system reacts to counter that change.

ACTIVITY 3. Differing Solubilities

Introduction

One aspect of the dissolving of solids in liquids, or of solution equilibria as they might be called, is that of substances with differing solubilities. NaCl is quite soluble, whereas AgCl is not so soluble. This activity will attempt to present the idea of differing solubilities. In addition, the problems involved in setting up an experiment are heavily emphasized. The teachers will have to work these problems out. Considerable help is provided.

Materials

dirt
dishpan
potassium nitrate (KNO_3)
sand (must be clean) (SiO_2)
calcium carbonate ($CaCO_3$)
sodium chloride (NaC1)
copper sulfate ($CuSO_4 \cdot 6H_2O$)
burners
5—200 ml. bottles and stoppers
5—500 ml. pyrex beakers

Procedure

Divide the class into five groups and give each a small sample of dirt and 100 ml. of distilled water. Ask the pupils to mix the dirt and water and let it stand until the next day. Have them describe what they observe. Ask what has happened. They may note that sorting of the particles has occurred at the bottom of the bottle. The water will probably look "cloudy." Someone will suggest that some materials have dissolved in the water. Ask if there is a difference in how much each dissolves.

Ask the class to design an experiment for determining whether or not different substances dissolve in different amounts. The teacher should let the class discuss and plan as much as possible. Consider the following questions if they are not discussed by the class:

1. *Once a substance has dissolved, how can we conveniently tell how much has dissolved?*

   Someone will probably suggest weighing the solid before and after mixing. This could be done, but it would require the drying of the solid that settles to the bottom. A better suggestion is to mix the solid and liquid together and let stand until thoroughly saturated (saturated solutions are solutions which have all the solid dissolved that will dissolve). Carefully measure out 100 ml. and place in a previously weighed 500 ml. beaker. Evaporate to dryness over a low flame. The solution may be boiled at first, but do not boil as the liquid approaches dryness. When the beaker has cooled, it can be weighed. The difference between the weight of the solid plus the beaker and the weight of the beaker is the amount of solid which dissolves in 100 ml. of liquid.

2. *Can tap water be used to dissolve the solid?*

   No, since tap water already contains dissolved solids. Have each group take 10 ml. of tap water and prove this point.

What then can be used in place of tap water?

Distilled water is nearly free of dissolved solids.

Is there any way of being sure that the water used has no dissolved solids?

Yes, evaporate a 100 ml. sample as is recommended in question 1.

3. *What solids can be used?*

Some solids are recommended in these materials, but others can be used. Carbohydrates such as sugars and starches will decompose if heated to a high enough temperature after drying. Therefore they are undesirable since they would generally not give good results.

4. *What conditions should be controlled? Does the amount of water used make any difference?*

No, not as long as the procedure recommended in question 1 is followed.

5. *Does temperature control make any difference?*

Yes, the pupil should be able to answer that temperature is a factor in equilibrium, so constant temperature is necessary.

How can constant temperature be maintained in these solutions?

A dishpan of water with the solution sitting in the water during the saturation process is one way of maintaining constant temperature. Also it affords a way of keeping the temperature of one solution equal to that of the other solutions.

Ask the class to outline a procedure to follow in setting up the experiment, using the questions or their own points as a basis for the outline.

ACTIVITY 4. Equilibrium in Acid Base Systems

Introduction

In the previous activity the use of the $Fe^{+3} + SCN^{-1} = FeSCN^{+2}$ system was examined. In this experiment another equilibrium system will be examined. This is the most common of the equilibrium systems because it is always present in systems containing water. The equation for this equilibrium is $H^+ + OH \longleftrightarrow H_2O$.

Materials

phenolphthalein
methyl orange
red cabbage
litmus
vinegar 2.4 to 3.4
ammonia 10-11
household ammonia
vinegar
20 test tubes
5 test tube racks
10 medicine droppers
10—50 ml. beakers

Procedure

Prepare the solutions of indicators in the following ways or borrow from junior high or senior high school teachers.

1. *Phenolphthalein.* Dissolve one gram in 700 ml. of 95 per cent ethyl alcohol and dilute with water to one liter.
2. *Methyl orange.* Dissolve one gram in one liter of water.
3. *Red cabbage.* Boil in water until the water is heavily colored.

In grade five a unit entitled "Chemical Systems" presents a basis for distinguishing between acids and bases. The teacher should review this unit and may wish to use the activity dealing with acids and bases if pupils did not do this unit in grade five. Even if they have done it, a few words of review would be wise.

Tell the pupils that they can distinguish between acids and bases according to the reaction with the indicator litmus.

Divide the class into five groups, giving each group two 50 ml. beakers, four test tubes, and two medicine droppers. Have the groups get 25 ml. of ammonia water and 25 ml. of vinegar. Give each two pieces of saran wrap to cover the beakers and reduce fumes. Have them use one dropper for the ammonia and one dropper for the vinegar. Be careful not to get the two confused. Direct them to place three ml. of ammonia and three drops of liquid indicator in each of the three test tubes. Use a different indicator for each tube and label the rack for each tube. Drop a small piece of litmus paper in the fourth test tube.

Tell the class to test each indicator, adding acid, drop by drop, until a color change has occurred.

The solution should be stirred after each drop. If for one indicator no color change occurs, wash that tube and place three ml. of vinegar in it. Then add ammonia until the color change occurs. In either case when this change occurs, stop adding vinegar (or ammonia) and reverse the process by adding ammonia (or vinegar). Reverse the color change again. Keep track of drops added and color changes that occur.

Tell the class that ammonia contains OH^- ions and vinegar contains H^+ ions. Indicators react with these ions in the following equilibrium:

$$H^+ + OH^- \longleftrightarrow H_2O$$

For a given solution with so many OH^- ions and so many H^+ ions, the addition of H^+ ions increases the number of H^+ because they react with OH^- to form water and reduce the OH^- concentrations. Conversely the addition of OH^- ions increases the number of OH^- and at the same time reduces the number of H^+ ions. These indicators react with the OH^- or H^+ when they reach a certain concentration. As the class has demonstrated, once the color change has occurred, the process can be reversed by adding a different ion. Discuss the above with the class.

ACTIVITY 5. Growing Crystals

[illegible]

During the evaporation of the salt solution, the pupils should have noticed that crystals formed on the bottom of the beaker. Other aspects of crystals have been presented here and elsewhere in sixth grade. Crystals are grown by carefully controlling those factors which affect a saturated solution. In this activity the class is to develop a procedure for growing crystals. Each pupil will have the opportunity to do this.

Materials

Materials will depend on what the pupils and teacher agree to do.

Procedure

Have the class research the topic of crystal growth. Have each pupil select a substance to use and set up an experiment for growing his own crystal.

ACTIVITY 6. Supersaturated solutions

Introduction

In previous activities the saturated solution has been presented as the limit of solubilities of a substance. In other words, when all of a solid that can dissolve has dissolved, it is said to be saturated. While this is generally true, it is not strictly true in every situation. One exception occurs sometimes when a saturated solution at a given temperature is cooled. Since the amount of solid which will dissolve in a given volume of solvent is temperature-dependent, a saturated solution will lose some of the solid when the temperature is dropped. This is not always what happens. Sometimes the solution remains in solution temporarily and is deposited when some impurity is added or when the solution is given a physical shock. Such a solution is called a supersaturated solution.

Materials

2—500 ml. florence flasks (must be clean)
cotton
sodium chloride (NaCl)
sodium thiosulfate (photographer's hypo)
burners

Procedure

Place 250 grams of hypo in one flask and 250 grams of hypo in the other flask. Heat both until the solid melts. Explain to the class that this is a solution, since water is trapped in the crystal when the hypo crystallizes. Without moving the flasks, allow them to cool. If either begins to crystallize, reheat both and do not let them cool as long the second time.

Drop a salt crystal into one flask and a hypo crystal into the other. No crystals form in the flask to which salt was added. But in the flask to which the hypo was added, crystals form very quickly. Be sure that the flasks are clean before starting the experiment.

The crystallization of a solid takes place in just a certain way. That certain way for hypo is not the same as for NaCl. Therefore, the hypo did not crystallize on the salt, but did on the hypo. Show how quickly the hypo crystallized out of this supersaturated solution.

Honey is a supersaturated solution. Try adding a sugar crystal to a test tube of honey, and stopper it. Let stand for a few days.

EVALUATION

Carefully examine the unit goals and set up questions which determine whether or not these goals have been reached. Some evaluation should be based on the lab work done. Another portion should be based on the contributions each youngster made in class.

1. One container of liquid A is at 100°C and another is at 95°C. What factors must be considered in determining which will dissolve the most of a certain solid?
2. Liquid B is saturated with solid X. How could this liquid be made unsaturated?
3. What factors must be considered in growing crystals?

GEO-SYSTEMS

EXPERIMENTATION is the means for testing hypotheses. It leads to increased understanding and knowledge concerning the real world. A basic activity of the scientist is the recognition and control of all factors which may affect the outcome of an experiment. Only through proper control of variables can experimentation produce meaningful results.

The variables involved in formation of earth materials, earth processes (mountain building, erosion, sedimentation), and all earth change are many. Hopefully, the elementary pupil will learn the significance of experimentation with one variable at a time in his investigation of the geosystem.

Unit Goals

Upon completion of this unit the pupil should be able to:

1. Design an experiment which includes proper control of variables.
2. Recognize the changing nature of the earth.
3. Identify the fundamental units of earth materials and ascertain the importance of these materials to the interpretations of the geologic history of the earth.
4. Understand that present earth processes are similar to the processes which have operated in the earth's past.

Unit Development

The pupil initiates his study of the geosystem by investigating the materials that comprise the earth's crust. An attempt is made to have pupils establish their own generalizations concerning chemical composition, mineral composition, and the rocks of the crust. The pupils will discover that rocks and minerals are more than names and collectors' items. They provide clues for the interpretation of the geologic history of the earth. A limited yet representative group of rocks and minerals is utilized to correlate earth materials with upcoming activities involving earth processes.

The evolving unit next emphasizes the processes that are constantly changing earth materials. Weathering and erosion are considered the primary processes of earth destruction. The building-up processes are deposition and mountain-building. An acquaintance with radioactivity serves the purpose of providing insight into the probable causes of mountain-building and rock-forming processes.

The unit focuses attention on earth materials as related to earth processes. For example, rocks are classified as to their origin. The origin of a rock is closely tied to earth processes. Effort is made to establish these relationships whenever possible.

The last phase of the unit emphasizes the time factor in relation to earth materials and earth processes. Stress is placed on the idea that most earth processes require an immense period of time to cause most changes. Measured geologic time indicates that time is a plentiful commodity. Therefore, similar processes of change have acted at rates in the past similar to those at which they are acting in the present.

Hopefully, the pupils will develop an awareness for the constantly changing nature of the earth and attach a new significance to the materials of the earth's crust.

It would be advantageous for pupils to experience a first-hand acquaintance with the geosystem. Therefore, if there are opportunities for local field trips or outside observations, arrange to give pupils this experience.

INTRODUCTORY ACTIVITY: Earthquakes, Volcanoes, Mountain-building and the Changing Earth

Introduction

This exercise should be completed as a class activity. The purpose is to acquaint pupils with distribution of earthquakes and volcanoes and to illustrate the relationship between these earth processes and mountain-building. The activity also emphasizes the constantly changing nature of the earth.

Materials

world map—large wall map which can be easily observed by the class
stick-pins, colored stars, etc.

Procedure

This activity must begin as soon as possible. All pupils should be involved with the collection and plotting of the data. Earthquake locations are reported in many local newspapers or papers of larger circulations. Direct the pupils to clip any such information for use in plotting the location on the world map. Use the stick-pins to mark the locations of the earthquakes.

If the earthquake locations are too few in number, have the students refer to *The World Almanac* or any encyclopedia for earthquake locations and the world earthquake distribution.

The class should also be assigned the plotting of volcanoes. Direct the pupils to collect information from any available sources on volcanic eruptions. Plot the volcano locations, using colored stars. Very few volcanic eruptions will be reported during the time interval of this unit. Therefore, pupils will have to refer to the encyclopedias, *The World Almanac,* or earth science textbooks for the distribution of volcanoes. Plot this information on the world map.

During the data-collecting interval, the teacher should encourage pupils to identify areas of active earthquakes and volcanoes. The developing patterns should indicate the relatively slow nature of earth changes.

This long-term activity will be utilized later in the unit. Hopefully, the resulting earthquake and volcano distributions will be sufficient for class analysis and discussion.

CONCEPT: Minerals and rocks reveal important clues about the origin of earth materials and the history of the earth.

ACTIVITY 1. Elements, Compounds, and Minerals

Introduction

Minerals are naturally occurring inorganic compounds or elements. This activity seeks to illustrate that minerals are compounds made up of smaller units called elements. The teacher may discuss elements in terms of similar atoms. Develop the concept of minerals as being composed of particular atoms with a particular arrangement of the atoms. This arrangement determines the physical properties of minerals.

Materials

pyrex test tube
test tube holder
bunsen burner or alcohol lamp
minerals (cinnabar, gypsum, stibnite, graphite, copper)

Procedure

Pupils may complete the activity in groups of three or four. However, pupils must be very cautious in their techniques. Break up the cinnabar (mercuric sulfide HgS) into small pieces or into a powder if possible. Put some of the mercuric sulfide powder into the pyrex test tube. Using the test tube holder, place the test tube containing the cinnabar into the flame. The test tube should be tilted away from the pupil while being heated.

Observe the results of the heating. Silvery drops of mercury should form on the upper part of the inside of the test tube. Also sulfurous fumes will be produced. Pupils should detect a sulfur odor. (Do not breathe the fumes directly.)

Discuss the two elements found in this mineral. The pupils will recognize that minerals are composed of elements such as mercury and sulfur, and that burning those elements forms a compound called mercuric sulfide or the mineral cinnabar.

Heat some crystals of gypsum ($CaSO_4 . 2H_2O$) hydrous calcium sulfide in a similar manner as the cinnabar. Again, when heating, point the test tube away from pupils. The heating should cause water droplets to form at the end of the test tube, thereby illustrating the presence of the common substance water in a mineral.

Stibnite (antimony trisulfide Sb_2S_3), if heated in a similar fashion, will form a sulfurous gas and antimony oxide.

Discuss these minerals in terms of elements and compounds so that pupils see the minerals in their proper perspective as one of the building units of the earth's crust. For example, cinnabar is composed of the elements, mercury and sulfur. The atoms of the elements combine to form a compound called mercuric sulfide (HgS). The inorganic mercuric sulfide occurs naturally in the earth's crust; therefore, it is called a mineral.

Native copper and graphite may be discussed in terms of minerals composed solely of one element.

ACTIVITY 2. Minerals and Crystals

Introduction

The pupil has been shown that minerals are made of compounds of various elements. The regular form assumed by a chemical compound when passing from the liquid or gas state to that of a solid is called a crystal. Many minerals are crystalline. The shape of the crystal is determined by the arrangement of the atoms of the compound.

Materials

pyrex beakers
hot plate or other heating source
water
weight (nail or bolt)
string
potassium alum ($KAl (SO_4) . 5H_2O$)
hand lens or any magnifying lens

Procedure

Groups of two to four pupils are satisfactory for this activity. Use about 1/4 cup of boiling water for each substance. Mix as much of the sugar, salt, and copper sulfate in the hot water as will dissolve. Add the materials slowly and stir constantly. Tie a weight to the end of the string and drop into the beakers containing the sugar, salt, and copper sulfate solutions. Let the other end of the string hang over the top of the glass. Allow the solution to cool slowly. In time crystals begin to form. Using the hand lens, observe how the crystals grow and notice the different shapes of the crystals. Pupils should note the conditions necessary for the growth of crystals.

The discussion resulting from this activity should include some mention of the variety of crystals displayed by formations of different substances. Principles of crystal formation should also be noted. An opportunity is provided here for discussion of variables in the growth of crystals. Have pupils suggest any variables in this investigation which might have caused variation in their results. The list might include:

1. Temperature of the solution.
2. Variations in the temperature of the solution.
3. Variations in the amount of the salt used.
4. Impurities in solution.
5. Variation in the amount of water used.

Have pupils design an experiment in which all variables are controlled except one. For example, everyone will control the amount of potassium alum that is used; the same water source and the same amount of water will be used by all. However, vary the temperature of the water. Some groups will use water at room temperature, some at 50° C, others at boiling temperature—100°C.

Discuss results of the experimentation. What is the advantage of controlling variables? Can all variables be controlled? This situation provides an excellent opportunity for discussing variables and the value of experimentation in scientific activities.

ACTIVITY 3. The Most Common Elements in the Earth's Crust

Introduction

Generally, pupils are not aware of the most common elements in the earth's crust. This activity introduces the eight most common elements and relates them to the chemical composition of the most common minerals.

Materials

pencil
paper
minerals (feldspar, orthoclase or plaioclase feldspar; quartz; hornblende; mica, muscouit, or biotite)

Procedure

This activity should be completed by the individual pupil. Ask the pupils to list the most common elements in the earth's crust. Usually, most pupils will list iron, copper, uranium, lead, silver, and gold. Most of these minerals are important but not common. Give each pupil or group of pupils examples of the minerals—feldspar, quartz, hornblende, and mica. Using any available reference material, direct the pupils to find the chemical composition of each mineral. The compositions are as follows:

Quartz - SiO_2

Feldspar Group
  Orthoclase - $KAlSi_3O_8$
  Albite - $NaAlSi_3O_8$
  Anorthite - $CaAl_2Si_2O_8$

Hornblende - $Ca_2\ (Mg,Fe)_5\ \ (Si_8O_{22})\ \ (OH)_2$

Mica Group
  Muscovite - (H, K) $AlSiO_4$
  Brotite - $H_2K\ (Mg,\ Fe)_3\ Al\ \ (SiO_4)_3$

In these chemical compounds, which elements are common to all (excluding the hydrogen)? Have the pupils list the elements.

K
Al
Si
O

Na
Ca
Fe
Mg

In all these compounds, which two elements have the largest number of atoms? Oxygen and silicon obviously have the greatest number of atoms in each compound.

What then is the average chemical composition of the earth? The teacher may present the following table:

The Common Elements in the Earth Crust
(Average Chemical Composition)

Element	*Symbol*	*Percentage by Weight*
Oxygen	O	46.6
Silicon	Si	27.7
Aluminum	A1	8.1
Iron	Fe	5.0
Calcium	Ca	3.6
Sodium	Na	2.8
Potassium	K	2.6
Magnesium	Mg	2.1
All other elements	—	1.5
		100.0

Discuss this activity in terms of minerals whose components contain these most abundant elements. These minerals then are the most common in the earth's crust. This activity leads to Activity 4 in which the pupil investigates these common minerals.

ACTIVITY 4. Investigating Common Minerals

Introduction

A mineral is an inorganic chemical compound which has a definite set of physical properties. This activity serves as an introduction to the identification of minerals based on their physical properties. The common minerals of Activity 3 are used as well as some which vividly illustrate some basic physical properties of minerals. Stress importance of the arrangement of the atoms in determination of the physical properties.

Materials

minerals (quartz, feldspar, mica-biotite and muscovite, hornblende, calcite, halite, pyrite, galena, magnetite, olioine)
penny
paper clip
glass plate
dilute hydrochloric acid
unglazed porcelain tile

Procedure

Initially, give the pupils the four common minerals—quartz, mica, hornblende, and feldspar. Ask the pupils to list the characteristics of each. Any word may be used in their descriptions. Suggest that they use the penny, paper clip, and glass plate to test for hardness (see if the minerals scratch the penny, the glass plate, or each other). Ask several pupils to read their descriptions.

After each pupil has read his description of one mineral, have the rest of the class indicate which mineral he is describing. Discuss how minerals can be identified and what properties are used for identification. If the pupil can learn some basic observable physical properties such as color, hardness, streak, luster, cleavage, and fracture, he can identify most minerals. Using the minerals suggested in the materials list, the teacher may allow the pupils to examine them in terms of specific properties (e.g., calcite—cleavage, non-metallic luster; halite—salt taste and cubic crystals; galena—high specific gravity; magnetite—magnetic; pyrite—metallic luster, etc.).

The emphasis in this activity is not the identification of many minerals or learning the names of them. Use the minerals to stress that they are composed of natural occurring chemical compounds, and the arrangement of the atoms determines the physical properties they are describing.

Pupils and teacher may wish to extend this activity and properly identify all of the minerals. Also, pupils will want to bring in minerals they have collected for identification. It is suggested that the teacher have several reference books on hand so the pupils may work on the minerals individually.

The teacher may write to the Iowa Geological Survey, Iowa City, Iowa, requesting a set of rocks and minerals indigenous to the state of Iowa. Two pamphlets may be obtained upon request: (1) *Rock and Mineral Collecting Areas in Iowa,* and (2) *Rocks and Minerals in Iowa.*

ACTIVITY 5. Investigating Common Rocks

Introduction

In previous activities, elements, compounds, and minerals have been investigated. The next logical step is a study of the larger units known as rocks. From a study of the mineral composition, the grain size (texture), and arrangement of particles (structure) of a rock, one can usually determine something regarding the rock's history. Therefore, the fundamental reason for studying rocks is the determination of their origin, which leads to a further understanding of the history of the earth.

Materials

rock specimens
  igneous—granite, gabbro, felsite, basalt, obsidian
  sedimentary—conglomerate, sandstone, shale, limestone, coal
  metamorphic—gneiss, mica schist, slate, marble, quartzile
hand lens or magnifying glass
teasing needle
dilute hydrochloric acid
knife, nail file, glass (for hardness determination)

Procedure

The activity should be carried out in small groups of two to four pupils, depending on availability of the materials (allow the pupils to use any tools listed under materials).

Remember the purpose of this activity is not to learn rock names, but to learn the basis for rock classification and the geologic history that can be interpreted from a rock.

First have the pupils look at the igneous rock specimens. Do these rocks resemble the crystals that were grown in Activity 2? What is the mineral composition of each rock? Why are some rocks lighter in color? Why are some rocks darker in color? (Note: This is an opportunity to emphasize the most common minerals and elements again. See the two preceding activities.)

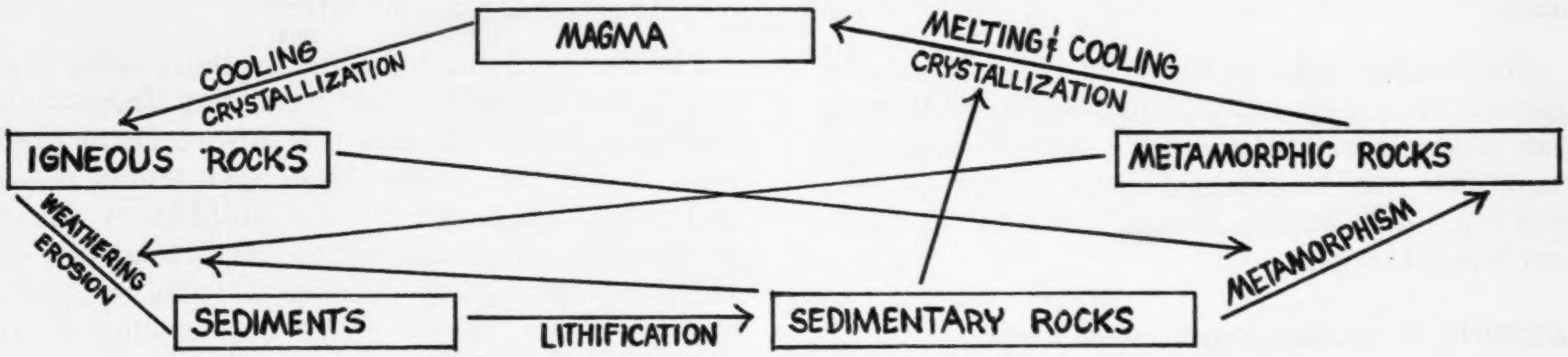
The pupils should indicate that these rocks were formed by the cooling and hardening (freezing) of molten material. Discuss the difference in grain sizes. Granite and gabbro have large grains, felsite and basalt small grains, and obsidian is glassy. In the discussion, attempt to have the pupils develop the relationship between the rate of cooling and grain size. Where could slow cooling of the molten material (magma) occur? At or near earth's surface. It is usually associated with volcanoes.

Next have the pupils investigate the sedimentary rocks. How do these rocks differ from igneous rocks? Have the pupils determine the mineral composition of each rock. Suggest that the rocks be classified according to grain size. Are any of the mineral grains rounded? What might cause the grains to be rounded?

Most pupils are aware that sedimentary rocks are formed through the deposition and compaction of sediments and chemical precipitates. Ask pupils what conditions might be present in a sea for the deposition of clay or fine grained salt and sand. How could the pebble-size materials in a conglomerate be transported? (Swift moving stream.) Limestone and rock salt are formed by precipitation from a solution. What conditions are necessary for the formation of rock salt? (Warm climate necessary for evaporation.) What origin and geologic history is represented by the coal? (Organic origin and usually associated with swamp-type environment.)

The common metamorphic rocks should be examined last, as they are considered to be rocks formed by the alteration of pre-existing rocks. These specimens should first be classified according to the arrangement of the particles. Some have a parallel arrangement of the minerals (banded appearance); others do not have this characteristic. What might have caused the arrangement of minerals? (Alteration due to heat and pressure.) Those metamorphic rocks which do not have the parallel arrangement indicate recrystallization of the minerals. Have the pupils determine the mineral composition of each rock.

In conclusion, discuss the three rock types and the basis for their classification. Emphasize the geologic history that may be determined from a rock specimen. Discuss how the three major rock types are related in terms of the rock cycle.



The rock cycle serves not only as a means of relating the three major rock types but also introduces the important concept of a changing earth. Included in the cycle are the basic earth processes of weathering erosion, deposition, metamorphism, and melting, which are developed in the next two concepts.

CONCEPT: Weathering and erosion are earth processes actively engaged in breaking down the earth's crust.

ACTIVITY 1. Weathering Process

Introduction

Weathering is a process occurring at or near the earth's surface. Weathering causes rocks to break into small pieces, dissolve, decompose, and by a combination of the above events, form soil. Weathering is subdivided into physical, chemical, and biological processes. (Remember weathering alters or changes rocks, and the removal of the altered material is erosion.) The weathering process should be approached as a means for change of earth materials. This serves to relate this activity to previous activities.

Part A - Can Freezing Water Break Rock?

Materials

two plastic refrigerator containers—one with a lid
masking tape
refrigerator
water

Procedure

This activity may be conducted as a homework assignment or as an activity for the entire class. Fill each container to the top. Put the lid on one container and seal by taping the lid on tightly. Set both containers in a freezer. If the outside temperature is below freezing, place the containers outdoors. Let the water freeze to solid ice. Observe the results.

What happened to the water level in the container without the lid? How might this happen?

What might have caused the lid to be pushed off the other container? Can there be enough force in freezing water to split rock? Water seeps into cracks of rock. If the water should freeze it will expand, thus providing a force that can split rock. The influence of this freezing force can be observed on cement roads, sidewalks, or rock exposures.

This is an example of the physical weathering process.

Part B - Chemical Weathering

As a result of the completion of Part A, the pupil will realize that both physical and chemical weathering processes are active in breaking down rock. Water, oxygen, weak acids, and other substances react with specific materials in rocks, altering or completely changing their composition.

Materials

litmus paper
soda straw
distilled water
steel wool
small box of clean sand
closed container
small pieces of limestone
small beaker
weak hydrochloric acid (four parts water to one part concentrated acid)

Procedure

The oxidation process may be illustrated in two ways. Suggest that each pupil group try to do one of the two. One method involves placing a piece of steel wool in a small box of clean sand and moistening daily. Have pupils make daily observations of the sand and the steel wool. The sand should become stained with an iron compound which you may call rust. The steel wool will rust when it combines with oxygen and water vapor in the air.

The second method involves putting a piece of steel wool in a container. Put a few drops of water in the container and seal with the lid. Observe the steel wool for several days. Iron oxide will form on the steel wool, indicating a reaction between the iron, oxygen, and water vapor. See if the steel wool is easier to break into pieces. If so, why?

What minerals in the various rock types contain iron? (Micas and hornblendes in most all the igneous rocks and some of the sedimentary and metamorphic varieties.) Iron in minerals often unites with oxygen and water vapor to form a mineral called limonite. Limonite stains rocks a yellowish red color.

Solution of limestone by a weak acid introduces another aspect of chemical weathering. Have pupils crush a small piece of limestone and place in a small beaker. Pour weak hydrochloric acid over the limestone pieces and let stand until it dissolves. Observe the reaction that takes place. There is a great deal of limestone in some areas of Iowa. Are there acids that will react with the limestone? To show how a weak acid may be produced, have the pupils blow through a soda straw into a glass of cold distilled water. (Note: It might take a good deal of blowing.) What two substances are combining to form an acid? (CO_2 and H_2O.) To test for acidity have the pupils put blue litmus paper in the solution. If the blue litmus paper turns red, the solution is an acid. Could this same solution be formed in nature?

Discuss the entire activity in terms of the constant change of earth materials. Re-emphasize the weathering process in terms of both physical and chemical processes. Stress the change of earth materials, not the removal of the materials, as the correct meaning of weathering.

ACTIVITY 2. Soils

Introduction

Soil is an important material to the agricultural industry in the state of Iowa. Many soils are formed from the weathering of solid rock. The purpose of this activity is to acquaint pupils with soil formation in their local areas.

Materials

None

Procedure

Have two or three pupils volunteer (or teacher may choose the pupils) to visit their county agricultural agent to learn the characteristics of soil types in their area and how these soils are formed. Have the pupils prepare an oral and written presentation to the remainder of the class. (Note: In many areas of Iowa soils are formed on transported materials and not from bedrock. Be sure pupils include this in their report if appropriate to your local area.)

ACTIVITY 3. Investigating the Rate of Erosion

Introduction

Weathering processes cause the rock to be broken into smaller pieces and may result in the formation of soil. It is a rather slow and unspectacular process. Erosion involves the transportation of the weathering products. Water, ice, and wind are the primary agents of erosion. Of these three agents, water is the most effective. In this activity, pupils will be introduced to the variables that determine the rate of erosion by running water.

Materials

empty aquarium
mixture of clay, silt, and sand
plastic tubing
large beakers (any large jar will do)

Procedure

This activity may be conducted as a demonstration or in groups of six to eight, depending on availability of equipment. Place the clay, silt, and sand mixture at one end of the aquarium so that it forms a large hill. Suggest that the hill represents a pile of weathered material. Using a finger or a spoon, make a one- to two-inch deep groove down the hill.

If there is a water faucet available, use the plastic tubing to carry the water to the aquarium. Otherwise, use the beakers and simply pour the water down the groove. In either case, let the water run down the groove so as to simulate a stream flowing downhill. Obviously, the stream will pick up some materials and transport them to the bottom of the hill. This represents a model of erosion by streams.

What factors will control the rate at which the stream will erode the hill? Discuss these factors in terms of their being variables. Have the pupils test any factors that are suggested. The two primary factors to be considered are the volume and the slope of the stream. In other words, varying the volume of water in the stream changes the rate of erosion. Varying the slope of the stream also changes the rate of erosion. The pupils can vary the volume of water by having two people pouring water into the groove on the hill, thus doubling the volume. The slope of the stream can be altered by changing the slope of the hill.

Discuss the other two primary agents of erosion. Stress the variables that will control the rate of erosion by wind and ice.

Pupils may extend this activity by doing some research in the library to learn how streams transport particles of earth materials. Another suggested topic would be how glaciers transport material.

Pupils should gain an understanding of the factors that control the rate of erosion rather than simply recognize the three primary agents of erosion. Erosion processes cause changes on the earth surface; however, the rate at which the changes occur is determined by many variables.

CONCEPT: Deposition (sedimentation) and mountain-building are earth processes that build up the earth's crust.

ACTIVITY 1. Deposition of Earth Materials

Introduction

Weathering processes break up and chemically alter rock. Erosion agents move and transport these particles. All the material that is transported by water, wind, and ice is called sediment. Rivers, carrying sediment, pour into the seas and deposit the sediment on the sea floor. Glaciers and wind deposit sediment on the land and in the seas. As the sediment is deposited on the ocean floor, layers are formed. This activity investigates some factors that control the rates of settling of sediments.

The activity also serves to relate sedimentary rocks to earth processes and earth changes. In time the layers of sediment became sedimentary rock.

While weathering and erosion are tearing down the land in one place of the earth's crust, sediment is being deposited in another place, thus building up the land.

Materials

gallon jug or aquarium
about one pint of each of the following: soil, clay, sand, gravel, pebbles
water

Procedure

This activity should be completed in groups of four to six pupils each. Place the soil, clay, sand, gravel, and pebbles in the aquarium or gallon jug. Add enough water so that the container is almost full. Either shake or stir the mixture very thoroughly. Then let the mixture stand. Pupils should record how the sediment settles to the bottom of the container. What materials settle out first? Why? Which sediment type settles out last? Why? Is this an accurate model of the deposition of sediments on the sea floor?

Suppose that the water were drained off, exposing the ideal arrangement of sedimentary layers. The coarse sediment (pebbles) would be on the bottom gradually grading into the finest sediment (clay or soil) on the top. Ask the pupils what varieties of sedimentary rock might correlate with the different layers of sediment in the model (e.g. sand—sandstone; clay—shale; pebbles—conglomerate).

Discuss how sedimentary rocks can give scientists clues as to the history of the earth. This activity should emphasize one of the major points of this unit—rocks are the means of interpreting the history of the earth.

This activity also provides an opportunity to experiment and control variables. Discuss with the pupils what factors may control the rate of settling of sediments. Logically, the size of the particles will be the most impressive factor after the completion of the previous section. What other factors might influence the rate of settling?

Shape and density of the sediments are variables which affect the settling rate. Ask the pupils to design an experiment which would involve only one variable—shape. The pupils can use the same container filled with water to work out their experiment. If problems develop with the design of the experiment, suggest that the pupils use two particles of the same weight but different in shape. Particles of quartz and mica would work well.

Other pupils might work with other controlling factors such as weight. They should design an experiment in which the size and shape are the same but the weight is variable. Two marbles differing only in weight would work satisfactorily.

Discuss the last section of this activity in terms of the experiments the pupils have developed and their manipulation of the variables. Are the results meaningful?

ACTIVITY 2. Mountain-building

Introduction

This activity utilizes the earthquake and volcano data procured in the introductory activity. The earthquake and volcano locations indicate the active, mobile area of the earth's crust. These are the areas where the mountain-building processes are going on today.

Materials

None

Procedure

First analyze the map to point out the active areas of the earth's crust. Discuss these locations in terms of the active earth processes that are acting to build up the earth's crust.

This activity should also emphasize that the earth is constantly changing. Many pupils might have the impression that mountain-building is an overnight process and the mountains rise out of the oceans in minutes of time. This activity provides an opportunity to "quiet these rumors." The earthquake activity is part of the mountain-building process, and it is a very slow process. Volcanism, on the other hand, is a very rapid earth-building process.

ACTIVITY 3. Heat Energy in the Earth

Introduction

Volcanism and earthquake activity indicate that there must be a source of energy to run these processes. Radioactive elements within the earth's crust and mantle are considered to be the source of energy. As uranium and other radioactive elements release particles and rays from the nucleus, heat energy is given off.

The heat given off by radioactivity within the earth may melt rock and form magma. The magma may push upward into the earth's crust and solidify or may be extruded from the earth's surface forming a volcano.

This heat energy may cause rock to expand and flow and cause an upheaval of rock above. This results in earthquakes and eventually over a long period of geologic time mountains may form.

Materials

None

Procedure

Have the pupils check any available references on the topic of radioactive materials within the earth and the production of heat energy. The relationships between the earth's heat energy and mountain-building processes are to be investigated. These topics should develop the relationship between heat energy, mountain-building, and the formation of igneous and metamorphic rocks.

The teacher may wish to have a short report on the pupils' library search. Use pupil reports as a basis for class discussion.

A project of this type emphasizes the importance of the library as a functional part of the scientific process of investigation.

CONCEPT: Earth processes operating today are assumed to have operated in a similar manner throughout the earth's history.

* * * * * *

There are no activities to develop this concept.

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Because of the nature of this concept, activities are obviously not easily developed. However, this concept lends itself to a discussion which might serve as a culminating experience of the entire unit. Throughout the study of this unit, pupils should have developed generalizations which directly pertain to this concept. A successful presentation based on the following topics may put their generalizations concerning earth materials and earth processes into proper perspective:

1. Weathering, erosion, deposition, and mountain-building processes have been active in the earth's past as they are today. The rates at which the processes occurred may have varied from time to time. However, it is assumed that the rates are fundamentally the same.

The seas advanced and retreated over the continents and deposited sediments. These comings and goings of the sea provided an almost monotonous theme which runs through geologic history.

Continents exposed above the sea went through stages of weathering and erosion over and over again. Mountains were built and destroyed. New mountains were built, then worn down.

These same activities are going on today but because of the slow nature of the changes pupils are not cognizant of the continuing processes. All of the earth processes are certainly prevalent in the present physical changes of the earth.

2. The processes of rock formation (erosion, deposition, metamorphism, melting, solidification, etc.) are related to earth materials. Obviously, this represents a cyclical phenomenon which is proceeding now as it has in the geologic past. Too often pupils perceive earth materials as unchanging substances.
3. The matter-energy interaction theme is related to earth processes and earth materials. The changing earth is a classical representative of this interacting concept.

EVALUATION

The evaluation techniques demonstrate the pupils' understanding of the geosystem, the complex processes of experimentation, and the manipulation of variables.

Give the pupils one rock (e.g., granite) and direct them to answer questions concerning the rock in terms of the following:

1. Discuss the processes involved in formation of the rock.
2. List and discuss the variables which might determine the rate at which the rock would weather and erode.
3. Identify the substances that make up the rock.
4. Discuss the effects of earth processes on this rock in terms of the rock cycle.

Give the pupils a mixture of minerals and have them isolate those minerals which would logically be found in an igneous rock, a sedimentary rock, or a metamorphic rock.

Do not require memorization of mineral and rock names. Evaluate the pupils' ability to determine physical properties of minerals or the origin and geologic history portrayed by a rock.

Evaluate pupil understanding of the relationships between earth materials and earth processes by examining their knowledge of the rock cycle.

SPACE-TIME SYSTEMS

IT IS IMPORTANT that the pupil develop the ability to make careful observations relating objects to both time and space. It is insufficient for him to be able to pass judgment on objects he observes; he must be able to describe them in meaningful terms. He should be able to visualize the path from one reference point to the other.

The art of mapmaking is very old, but no less important today than in 1492. Not only must the pupil be able to visualize pathways, but he must understand something about motion along these pathways. He should experience the concept of the dimensions of motion.

Motion of objects relative to each other is a problem which has long perplexed man. The motion of the stars, the retrograde motion of the planets—even the phases of our moon are problems for which the solution was slow.

Unit Goals

At the end of this unit the pupil should be able to:

1. Construct actual serial arrangements of objects in two-dimensional and three-dimensional maps.
2. Understand how different maps are made and how they can be used.
3. Prove that motion is a relative term.
4. Understand that motion is related to space, time, and direction.
5. Differentiate between linear and rotational motion.

Unit Development

The first concept deals with representations of space-maps. One of the first problems is that of the map as a projection from the spherical surface to the more convenient map with a flat surface. The pupil is introduced to the problems of fitting a flat surface to a sphere; then he is asked to figure how to flatten a sphere to a flat surface; and finally he is asked to make a projection for a globe on to a flat surface.

The second activity is intended to acquaint the pupil with what he can find on a map. The aspects of location, scale, legend, direction, elevation, and contours are included.

The third activity is the construction of a two-dimensional map. The fourth activity presents the problem of representing the third dimension on a map. In addition to contriving contour lines, the pupil is exposed to maps with contour lines on them.

The last concept developed in this unit is that of relative motion. This is done through the use of problems and class discussions. It is a very difficult topic to present in a pupil-centered approach, but with skill on the part of the teacher this can be done.

CONCEPT: **A map is a two-dimensional representation of portions of the earth's surface. It attempts to show various natural and man-made features in their relative positions in space and time.**

ACTIVITY 1. Map Projections: From a Sphere to a Flat Surface

Introduction

The purpose of a map is to reduce the picture of the world or parts of the earth to a usable size. The earth is a sphere. A map is flat. Therefore, in the construction of a map, the transferring of latitude and longitude lines or any other lines from the sphere to a flat surface becomes a problem. This activity illustrates one method of transfer (projection) and points out the distortion resulting from this projection.

Materials

ruler
tennis balls, hollow rubber balls, ping pong balls, etc.
scissors, tin snips, or other cutting tools
globe model of earth
Mercator map (wall map) of world
white butcher shop paper or wrapping paper
marking pens
string

Procedure

Part of this activity may be completed as a teacher demonstration, but other parts should be done in pupil groups.

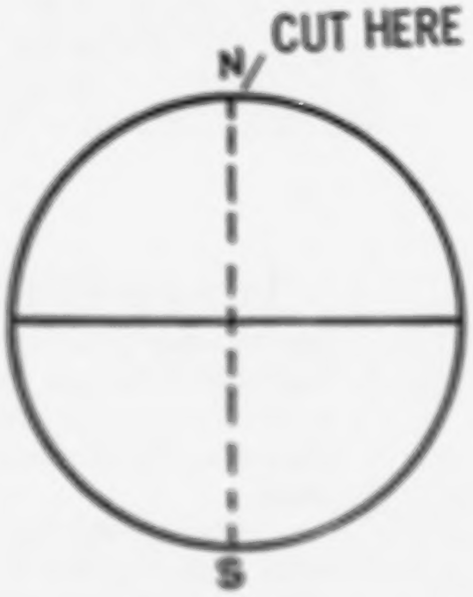
Part A—Teacher Demonstration

Using the globe and the Mercator map, point out the obvious. The wall map is flat; the globe is nearly spherical. Ask the pupils if it is possible to flatten the surface of the globe without tearing or distorting the surface. Discuss any pupil suggestions concerning this problem. It should become apparent to the class that a sphere cannot be flattened without tearing or stretching. To illustrate the above problem, and to satisfy any curiosity, move on to Part B of this activity.

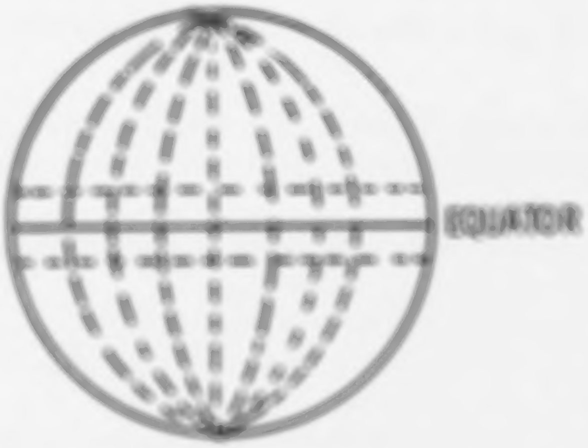
Part B—Pupil Group Activities

This section should be completed in groups of three or four pupils each. Direct the pupils to take the sphere (tennis ball, hollow rubber ball, ping pong ball, etc.) and mark imaginary north and south poles and the equator on the sphere. The problem as proposed in Part A amounts to making a sphere's surface lie flat, and identifying and observing the results.

First have the pupils cut the ball from pole to pole.

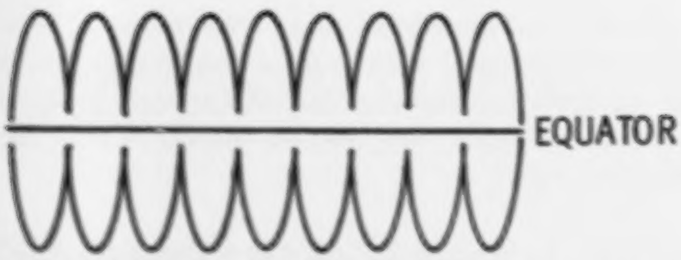


After cutting, allow pupils to try to flatten the sphere. Suggest that more cutting is needed to allow the sphere to flatten without tearing. Now have them cut "pie-shaped" sections from the north pole of the ball to about 15° latitude above the equator. Make about eight to ten "pie-shaped" sections of the northern hemisphere.



Now cut up the southern hemisphere in the same fashion.

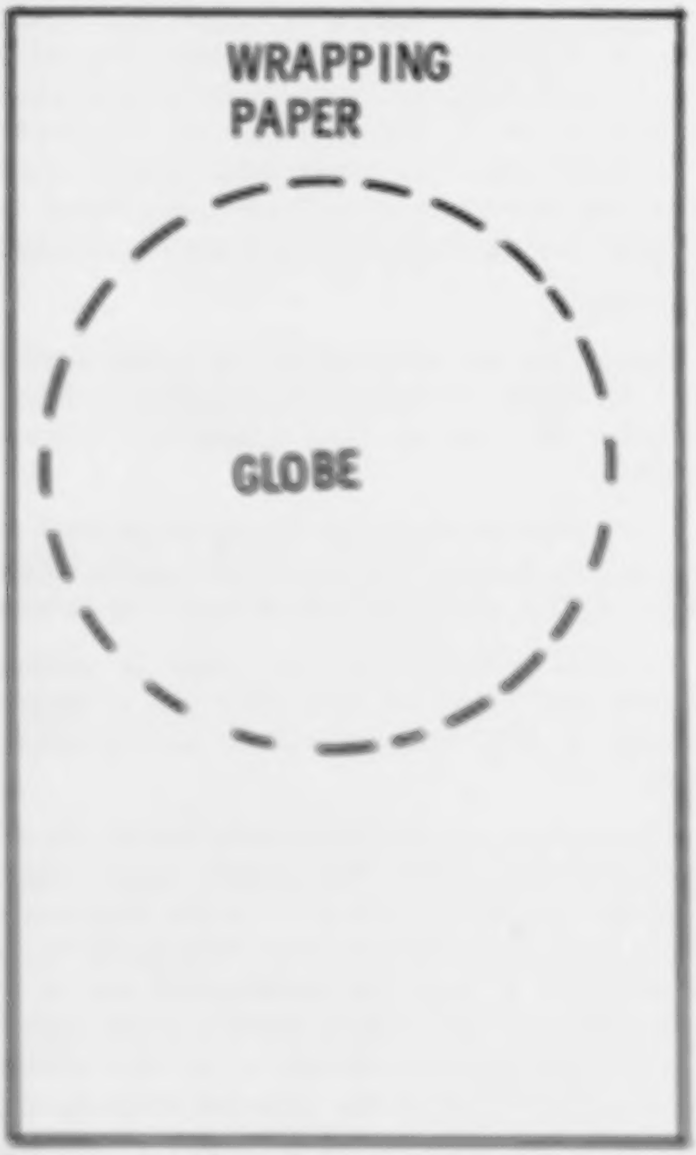
After cutting the ball in this manner, the pupils should almost be able to flatten the sphere surface. However, there will still be some bumpy nature to the surface and some stretching. Have pupils observe and draw the resultant form.



It should now be obvious that there is a definite problem in transferring lines from a surface of a sphere to a flat surface. The development so far should cause pupils to ask how the flat wall maps are made. They might have suggestions which may be discussed. After class discussion, go on to Part C.

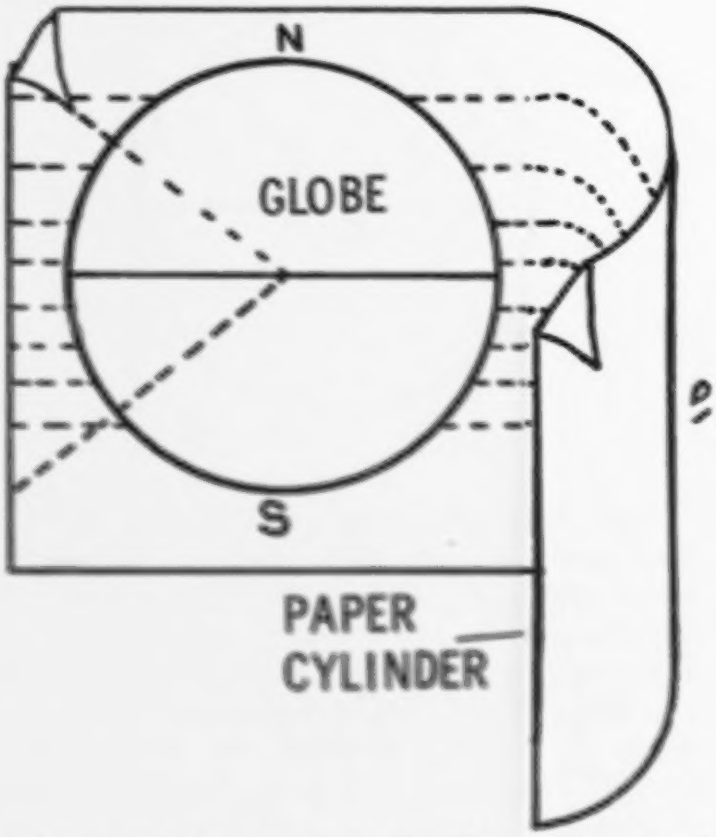
Part C

This activity should be conducted in groups of four to six pupils, depending on availability of the equipment. Using the globe and the butcher shop or wrapping paper, wrap a cylinder of paper around the globe.

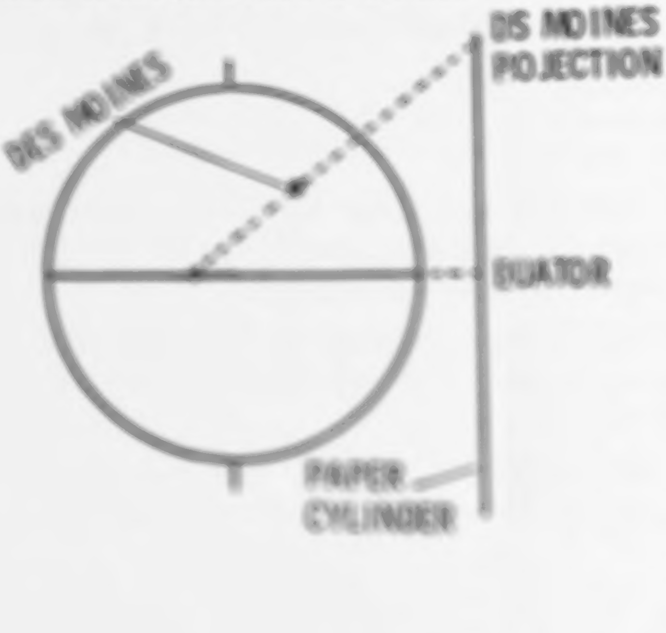


Discuss the idea of projection with the pupils. Have them identify projection as the extension of all earth features and lines on the globe to the paper cylinder wrapped around the globe. After projecting all points on the paper cylinder, merely unrolling the cylinder will show the earth on the paper. This is the basis for the Mercator projection.

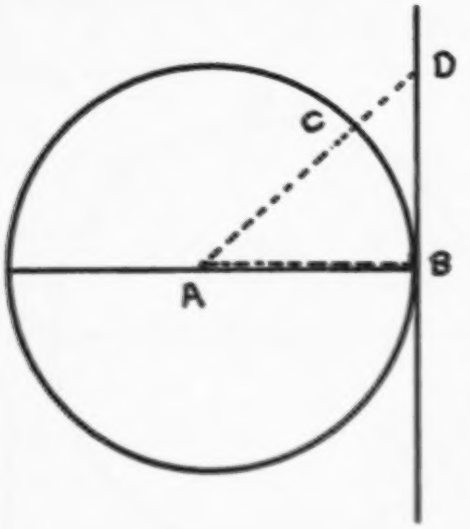
Direct pupils to make projections from the globe to the paper cylinder. These projections, admittedly, will be rough approximations but will serve the intended purpose.



Select two points such as Des Moines, Iowa, and a point on the equator directly south of Des Moines. Project the equational point (90° to the surface of the globe) to the paper cylinder. This should be simple. Now project the point represented by Des Moines out to the paper cylinder. Emphasize that the line of projection must be perpendicular to the surface of the globe at Des Moines.

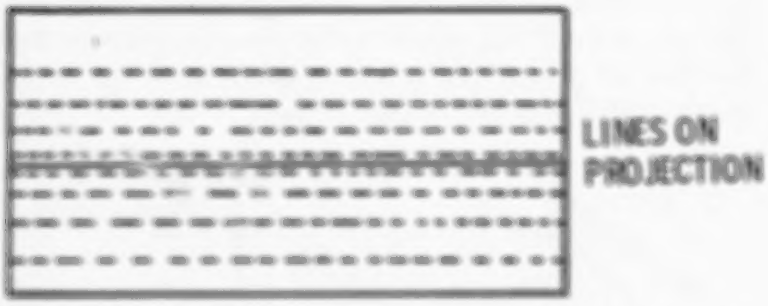


Unfold the paper cylinder and measure the distance between the dots. Then, using the string, direct the pupils to measure the distance between the two points directly on the globe. Holding the string at the appropriate spots, measure the length between the two points on the globe. Which of the two lengths is greater? Why?



Have the pupils draw a diagram similar to the illustration to help their understanding of this point. What is significant about this activity? What happens to distances between points on the paper cylinder as you go north and south of the equator? (Another example for measurement: distance between tip of South America and a point directly north of the equator. Use same procedure as above.)

On Mercator world maps, the distance between lines is distorted. As you go closer to the poles, the distance between points is much greater than the true distance on the sphere.



Therefore, what about the size of Greenland or Alaska on the globe compared with its distorted size on the Mercator projection?

What advantages does the Mercator wall map have? (It shows true directions that are easily determined.)

Hopefully, the pupils will have gained some insight into map-making from this activity. However, it should be mentioned that wall maps that comprise only a small area (e.g., a county) do not have the extensive correction for distortion. In a small area like a county, the area on the earth's surface is essentially flat.

ACTIVITY 2. What Is Included in a Complete Map?

Introduction

This activity, although elementary in some phases, serves to introduce what is included on a map. A complete map must include the title, legend, scale, evidence of location, and direction. The pupil should become acquainted with the meaning of these terms and how they are used.

Materials

road map (Iowa road map)
topographic maps (of local area if possible)
globe

Index maps showing the topographic coverage of the state may be obtained by writing Map Information, U. S. Geological Survey, Denver Federal Center, Denver, Colorado. From the index map, you can determine which topographic map encompasses your local area. The topographic map is ordered from the same place. A folder describing topographic maps and symbols is available on request.

Procedure

Depending on the number of maps available, have the pupils work in as small groups as possible. It would be best to have a map for every two persons.

Using first the topographic map of the local area, proceed to develop the points concerning location, scale, legend, direction, and evidence of location.

Location is shown on most maps by numbered latitude and longitude lines. This grid of lines was created by man but is based on natural relationships.

What is the natural relationship between latitude lines and the earth? The teacher might want to have the pupils do Activity 1 of the first concept of the fifth grade Astrosystem. This would be good review even if they had investigated this in fifth grade. What is the latitude reading at the equator? What is the apparent altitude of the North Star at the equator? What is the apparent altitude of the North Star in your town? What is the latitude of your town? What is the latitude halfway between the poles? In what direction do latitude lines run?

(East-west.) In what direction do latitude lines measure? (North-south of equator.) Emphasize the natural relationship for latitude lines.

What is the natural relationship between longitude lines and the earth? Have the pupils observe a globe and identify the axis or rotation of the earth. Do the north-south lines run through the poles? In what direction do longitude lines run? (North-south.) In what direction do longitude lines measure? (East-west.) Where do you start measuring longitude? Suggest that the starting point for longitude cannot be located at any natural halfway point such as the equator for latitude. Point out the prime meridian running through Greenwich, England, as the arbitrary starting point for measurement of longitude. From the prime meridian, distances are then measured east and west, meeting at the 180th meridian.

Any point on the earth may now be exactly located by giving its latitude in degrees and direction from the equator and its longitude in degrees and direction from the prime meridian. Have the pupils locate any number of points, using the globe to become acquainted with this grid system.

Now turn to the topographic map. Direct the pupils to locate the latitude and longitude designations for this map. The readings are located at each of the four corners. Use the readings in the lower right-hand corner. Can you tell just from the figures which is latitude and which is longitude? Have the pupils explain the basis for their decisions. Will you always be able to decide from any set of numbers on any map? Have pupils give examples of cases where they might not be able to tell.

As you move north (the top of the map) along this right-hand boundary, does the latitude increase or decrease? Are you moving toward the equator or away from it? Are you north or south of the equator? How does one know whether the longitude is east or west?

The size of the area as shown on the topographic map is obviously much smaller than the real size of the corresponding area on earth. The ratio of the distance on the map to the actual distance on the earth is called the scale.

Have the pupils locate the scale of the topographic map, on the bottom margin. The scale is given in two forms. For example, the fractional scale (1:24,000 to 1:62,500) indicates the distance ratio. This is a simple unitless fraction. It means one unit of length on the map represents so many of the same units on the surface of the earth; e.g., 1:24,000 means one unit on the map equals 24,000 units on the ground. The unit used by the U. S. Geological Survey is the inch. Below the fractional scale is the graphic or linear scale. An actual ground distance may be determined by comparing the map distance to the graphic scale.

Direct the pupils to locate the distance between various points on the map, using the fractional and graphic scales.

The legend of a map explains what the various symbols on the map mean. The U. S. Geological Survey topographical maps use symbols which are described in a free folder. The folder is available upon request (see materials.) The following are points characteristic of the symbols used on these maps:

1. Water features are printed in blue on topographic maps. These features include streams, rivers, canals, lakes, glaciers, etc.
2. Man-made features such as houses, roads, schools, etc. are usually printed in black. A school has a flag associated with the black symbol for the building. The major highways are usually red.

Direct the pupils to study the topographic map of the local area and interpret the symbols that are used.

Typically maps are drawn so that north is at the top of the map. Direction can be obtained by determining latitude and longitude. The U. S. Geological Survey topographic map is oriented so that north is toward the top, south toward the bottom, east toward the right, and west toward the left. North directions are usually given on the bottom margin of the map.

The teacher should allow the pupils to become fully acquainted with map directions. It might help to have them point the top of the map toward north. This will help them to develop the proper directional relationship with the local area.

Using the Iowa highway map, direct the pupils to determine and work with as many of the factors and features of maps as they can. They should be able to determine direction; interpret symbols used; determine distance, using the scale; and utilize the method of location which is not the latitude and longitude grid on most highway maps. The pupils should have enough experience with this map to use it in an accurate way.

ACTIVITY 3. Constructing a Two-Dimensional Map

Introduction

The pupils have been introduced to what a map represents and what things may be determined from a map. This activity intends for the pupils to put this knowledge and experience together to draw their own maps.

Materials

paper
pencil
colored pencils

Procedure

Allow the pupils to select an area which they can map. This area should, by necessity, be relatively small in size. Suggest the school yard; the block in which one of their houses is located; even a room in the school or in a house. The features of maps discussed in the previous activities (Activity 1 and 2) should be used in the drawing of the map.

Location (not necessarily latitude and longitude), direction, a scale, a legend, and a map title should be found on the map.

If desirable, the pupils may develop a scale in which the unit is one city block. For example, one inch on the map is equal to one city block. Any scale may be utilized as long as it portrays the features in a reasonable fashion.

Depending on the scale of the map and the area mapped, pupils may use any size of paper. Symbols might be color-coded and may utilize the symbols of the U. S. Geological Survey or symbols created by the pupils.

Materials

small aquarium, plastic shoe box, or some other
  water-tight container
sand
topographic map of the local area (see Activity
  2 for instructions for procuring this map)
marking pen or grease pencil

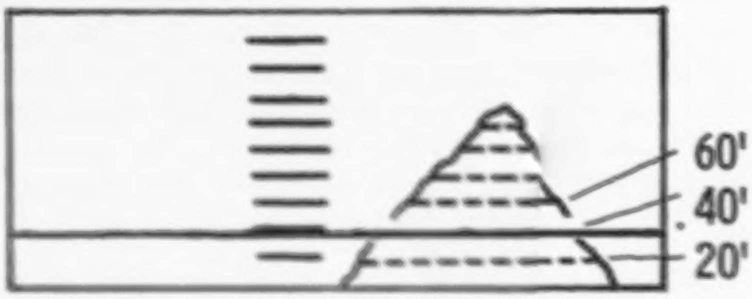
Procedure

This activity should be completed in as small groups as possible—preferably two to four pupils per group.

Using the aquarium, plastic shoe box, or other comparable container, direct the pupils to measure and make one centimeter intervals up the sides. With the marking pen or grease pencil draw lines through the marks. These lines will represent equal elevations and will be used to construct contour lines.

Next have the pupils make a pile of sand in the box. The shape of the sand pile is not significant. The pile of sand should be about one-fourth to one-half the height of the container (depending on the latter's size). Pour water into the container so that the water level is even with the first mark on the side of the box. Mark this first level as 20 feet. What is the elevation of any point on this level? What is the elevation of the line that is formed by the intersection of the water level and the sand? This line can be called a contour line. Are all the points on the contour line of the same elevation? Sketch and label this 20-foot contour line on paper.

Next add enough water so that the water level is even with the second mark on the side of the container. Mark this second level as 40 feet. What is the elevation of any point on this level? What is the elevation of the line formed by the intersection of the water level and the pile of sand? What is this line called? What is the difference in elevation between the first and second levels? This difference of elevation (20 feet) is called the contour interval. Direct the pupils to carefully sketch the 40-foot contour line and label.



Continue filling the container to each mark and determine the elevation represented by the contour line. Sketch each contour line on the diagram. (When the pile of sand is completely covered, there obviously is no line of intersection so pupils will stop filling the container.)

Discuss the resulting diagram in terms of adding the third dimension to a two-dimensional map. Stress that all points on a contour line are at the same elevation. Indicate that the contour interval must be known to determine elevations on a map. What is the base line or zero elevation on any map using contours? (Sea level.)

Refer now to the U. S. Geological Survey topographic map of your local area. Ask the pupils to locate the contour lines on the map. What color are the contour lines? (Contour lines on a topographical map are usually printed in brown.) What is the contour interval of the map? (The contour interval is located on the bottom margin of the map.)

Using the contour lines and the contour interval, have pupils determine the approximate elevation of several known features in the area. The teacher may develop this phase of maps as he sees fit. However, do not overdo the interpretation of contour lines (e.g., contour lines upstream, the closer the contour lines the steeper the slope.) Hopefully, the pupils will be able to visualize the third dimension on the two-dimensional map. This requires the formation of a spatial image in the mind of the pupil, and is typically a difficult concept to comprehend.

Time is an important related factor in dealing with maps. A map portrays portions of the earth's surface in its relative position in space at a particular time. In reality, any map represents a portion of the earth's surface only at the time it was made. Natural earth changes and man-made changes alter the earth's surface.

Direct the pupils to alter the shape of their pile of sand. This should be a significant change in shape. Does the original contour map accurately represent this pile of sand? Obviously, the original map does not accurately represent this feature because of the change in shape with time. Suggest that the pupils draw the contour lines to accurately represent this new feature.

Using the U. S. Geological Survey topographic map, determine the date it was made. (Date usually given on bottom margin of the map.) If you are using the map of your local area, try to find any changes (natural or man-made) that illustrate a map's relationship to the time factor.

Extending the Activity

Direct interested pupils in the addition of the third-dimension to their map of Activity 3. Be sure they select a reasonable contour interval to fit the relief of the area. Have them devise methods for determining the elevations. This might require some library research.

Some pupils might locate some paleographic maps in earth science textbooks, encyclopedias, or other sources. These maps illustrate a portion of the earth's surface during a particular time in the geologic past.

CONCEPT: All motion is relative to the observer.

ACTIVITY 1. How do you measure speed?

Introduction

When a little boy stands by the railroad track and watches a passenger train go by, he can see the waiter serving dinner in the club car. The boy can see the motion of the train and the motion of the waiter as he walks up and down to serve the diners. If the boy were riding in the club car, he would only see the motion of the waiter. If the boy were sitting on the moon with a powerful telescope, he would see the motion of the train, the motion of the waiter, and the motion of the earth. So in the final analysis, whatever motion the boy observes depends on his position at the time he makes his observation.

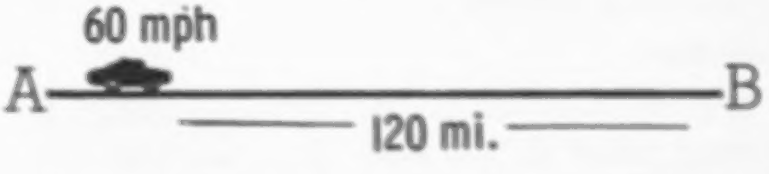
Materials

paper
pencil

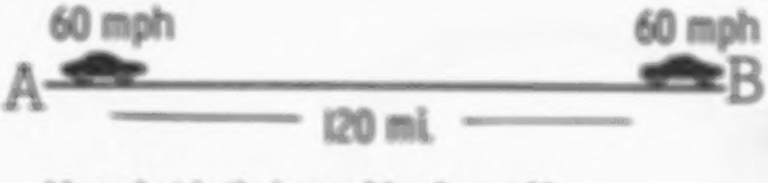
Procedure

In this activity the pupils can best work at their seats with a paper and pencil. The nature of this topic calls for much more teacher direction than many other topics.

Pose this problem to the class: If a car were traveling from town A to town B at 60 m.p.h and towns A and B were 120 miles apart, how long would it take the car to reach its destination?

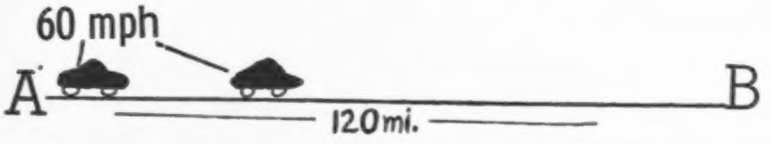


Once the majority of the class have solved this problem, ask them to think about it. If Car A left Town A headed for Town B at 60 m.p.h and Car B left Town B, headed for Town A at 60 m.p.h, how long would it take them to meet?



Also what is their combined speed?

Now ask the pupils: If Car A left Town A one hour before Car B left Town A so that both were traveling in the same direction and both were traeling 60 m.p.h., how much would Car B gain on Car A?



At this point the teacher should lead a class discussion concerned with relative speeds and points that should be covered. These points include:

1. All previous answers depended upon the relative position of Car A to Car B.
2. They always approached a town at 60 m.p.h.; but when they were headed at each other, they approached each other at 120 m.p.h.
3. When Car A and Car B were both going in the same direction, they approached each other at 0 m.p.h. As far as they were concerned they might just as well have been standing still.

ACTIVITY 2. Relative Motion in the Universe

Introduction

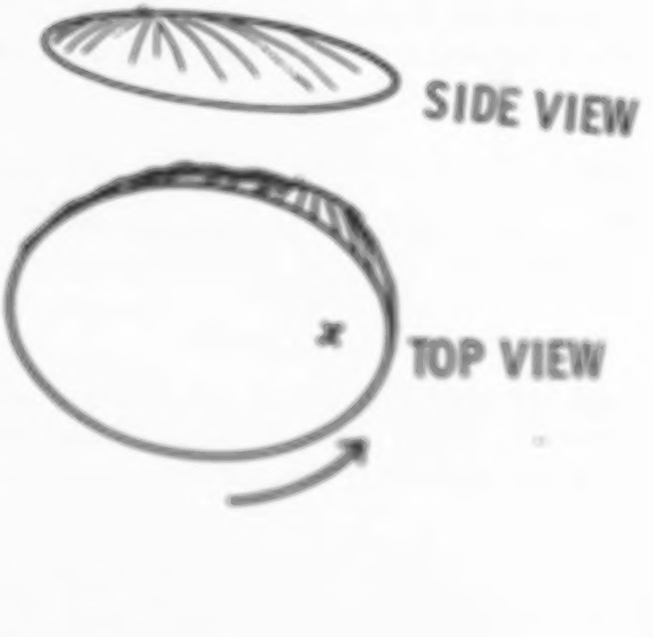
Astronomers are always faced with the problem of what to use as a reference point in the universe because everything seems to be in motion in relation to everything else.

Materials

model of solar system
pictures of galaxies

Procedure

With the pupils seated, the teacher should draw a rough model of the Milky Way galaxy on the blackboard.



On this model they should put an X in the approximate position of the star which we call the sun and an arrow indicating the direction of rotation of the galaxy. Now ask the pupils if they have ever felt the galaxy move. This should provoke quite a bit of discussion. Then ask them to make a list of motions that a person standing in Iowa would be subjected to in terms of the total universe. Tell them to use the information you have given them about the galaxy and any other information they can gather.

Next class period compile a class list on the blackboard from the pupils' list. This list should include:

1. The motion of the galaxy through space.
2. The motion of the galaxy as it revolves.
3. The motion of the earth as it revolves about the sun.
4. The motion of the earth as it rotates every 24 hours.
5. The motion of a person if he moves at all on the planet.

The teacher should lead a class discussion after the list is on the board. One motion that the pupils might not list is the wobble of the earth on its poles. This is a slight motion, but if it is mentioned be sure to include it. In the class discussion, ask the class how many of these motions are apparent to them. Ask them what conditions would be necessary for these motions to be apparent.

Ask the class if the people before Copernicus were justified in thinking that the earth was the center of the universe.

End the discussion by adding several more to the list of five motions. With the help of the pupils, this might be as follows:

6. Boy riding a train.
7. Motion of bouncing ball on the train.
8. Motion of ant crawling on bouncing ball.

There are many ways to add to the list, and all are valid.

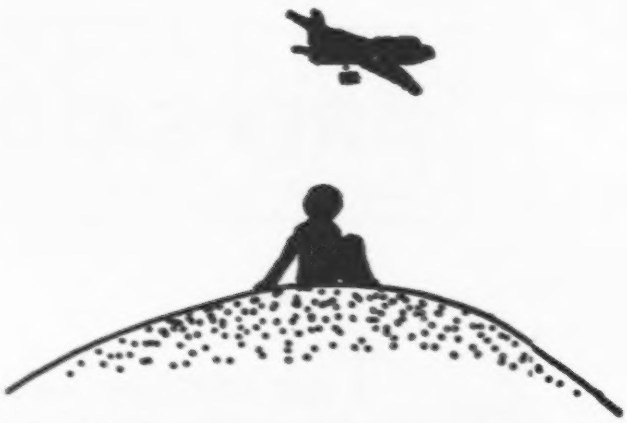
EVALUATION

Carefully consider each goal and construct a question or an activity which attempts to determine whether it was achieved. The following are some sample questions:

1. Tommy ties his dog to a stake on a six-foot leash. He notes that the dog likes to walk

around and around keeping the leash taut. He counts the paces the dog makes in one trip and finds that the front feet make 41 paces and the dog walks around the circle five times in a minute. How many steps does the dog make per minute (ignore hind feet)? If all other things were equal, would the dog's speed change if the leash were lengthened? What is the dog's r.p.m.? Would the r.p.m change if the dog were paced on a shorter leash? If so, how would it change?

2. Describe the motion of the shadow of a flag pole on a sunny day from sunup to sundown.
3. Produce the following contour map and ask the youngsters to label the highest and lowest point, the rivers and flat lands, and the highest slope.
4. An object is dropped out of an airplane. A boy on a hill nearby sees the plane drop the object. (It has no chute.) What path will the object appear to take as far as the boy is concerned?



5. In the above example, suppose you are a fly taped to the bottom side of the plane. How would the object appear to you to move?

REPEATING SYSTEMS

THIS UNIT will concern itself with systems which repeat themselves. The skills that will be stressed are *controlling variables* and *experimenting*. These go hand in hand because, to conduct an experiment, it is necessary to control as many variables as possible. One most often practiced method of controlling variables is that of having a control group. Everything happens in both groups except the one variable being investigated.

Unit Goals

At the end of this unit the pupils should be able to:

1. Identify a cyclic nature where one exists.
2. Identify the components of a cyclic system.
3. Identify variables in an experimental situation.

Unit Development

There are many things of a cyclic nature, such as sunspot cycles, rock cycles, water cycles, life cycles, and gas cycles. This is just a sampling of a much larger list.

Many cycles probably have not yet been identified. This unit, however, will concern itself with the last two cycles mentioned, the life cycle and the gas cycle.

The repeating nature of life will be investigated first: birth, life, reproduction, and death. Several approaches on different levels will be used in this investigation.

The second half of the unit will deal with the gas cycle of carbon dioxide and oxygen and how this enters into a living system.

CONCEPT: A primary concern of all living organisms is to reproduce their own kind.

ACTIVITY 1. Meal worms

Introduction

Meal worms are the larvae of the grain beetle, *Tenebrio molitor*. The beetle goes through its life cycles in four stages—the egg, the larvae, the pupa, and the adult beetle. These four stages can be found existing all at the same time in a colony of meal worms, and many individuals can be found in the process of making the change from one form to another.

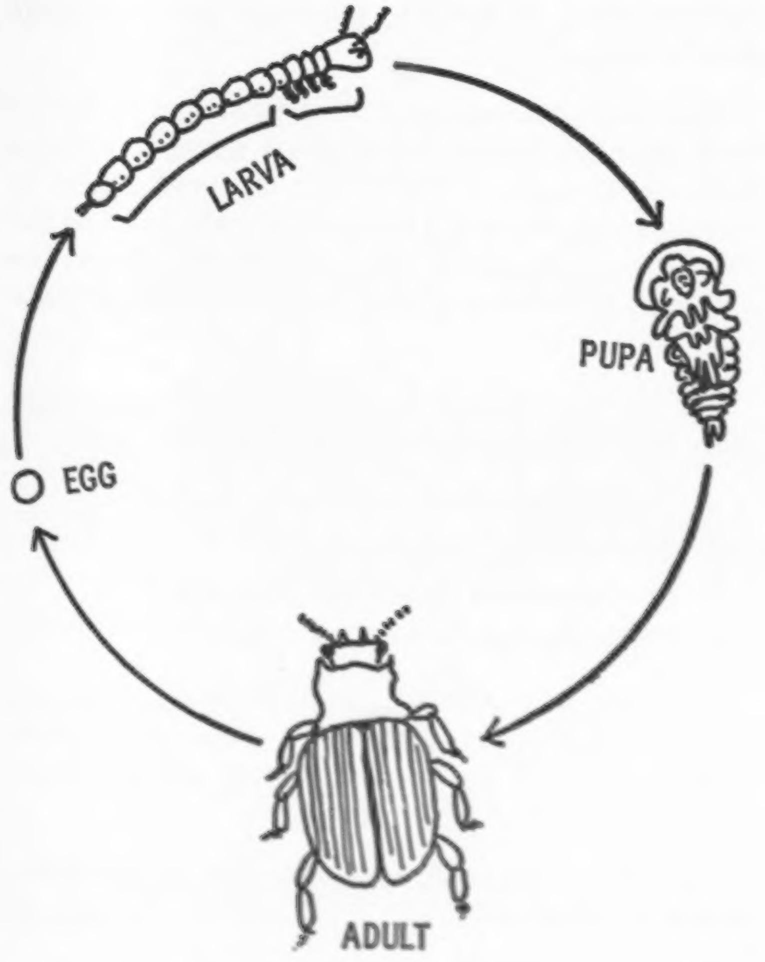
Materials

wide-mouth quart jars
bran
potatoes
meal worms, available at pet or fish bait shops

Procedure

Once the meal worms have been obtained, they should be placed in a wide-mouth jar which has been prepared by adding about one inch of bran in the bottom and two or three pieces of raw potato on top of the bran. Each jar can safely support 50 meal worms.

The class should set up as many jars as possible but no fewer than five. One jar should be placed in a refrigerator, one in a cool part of the classroom, and one in a warm part of the classroom. From daily observations, records should be kept and the



number of days noted until the first adult beetle appears. When several jars have adult beetles in them, ask the pupils to form a hypothesis as to why meal worms in certain jars become adults first. (Note: Do not wait for the meal worms in the refrigerator to become adults, as this will take much too long.)

During the time the class is making daily observations, each member should find himself an egg, a larvae, a pupa, and an adult beetle. The pupils should be able to infer that these are distinct steps but that they occur as result of a gradual process of change, which is the life cycle of the individual.

Conduct a class discussion about meal worms and their life cycle to culminate this activity.

1. Can this cycle be applied to other animals?
2. What effect did temperature have on the life cycle?
3. What did the larvae and adult beetles feed on?

After this discussion, let pupils take the meal worms home and see how many generations they can raise. Mention that the bran and potatoes should be changed every month or so. After class members have carried this activity on for several months, have them report the results to the class.

ACTIVITY 2. Hatching frog eggs

Introduction

In the spring frogs come out of hibernation and lay their eggs to start again their life cycle. Children have always been attracted to tadpoles as pets, so this becomes a very easy way to study another life cycle.

Materials

toad or frog eggs
shallow glass dishes
aquarium

Procedure

The first thing needed for this activity is frog eggs. There are several ways to obtain them. Take the class on a field trip if you know of a nearby area where the eggs may be collected. Or you may collect them yourself. Some pupils may be willing to bring in enough for the class. The biology teacher might be able to supply frog eggs or help you purchase some from a biological supply house.

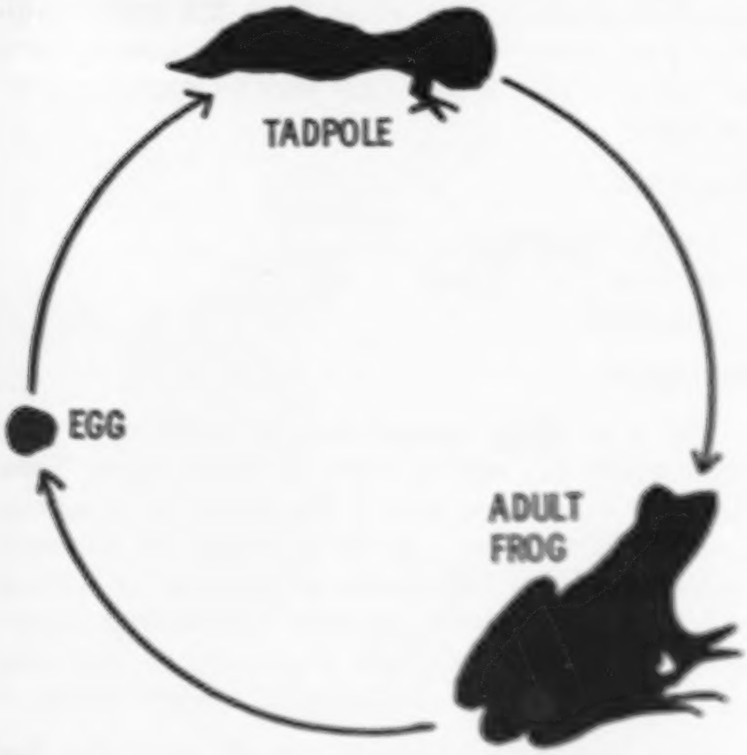
Once you have obtained enough eggs for the class, give each of four or five groups 20 to 30 eggs and a glass dish at least six inches wide and one and one-half to two inches deep. Have each group fill the glass dish with pond water or tap water that has been allowed to stand 24 hours or more. Then add the eggs. The eggs should be observed daily and observations recorded. If a dissecting microscope is available, the eggs should be observed under the microscope each day and drawings made of what is seen.

At the time the eggs are collected, it should also be possible to collect some tadpoles. These should be put into an aquarium and observed daily. Records should be kept. If tadpoles were not collected with the eggs, the teacher will have to wait for the eggs to hatch into tadpoles. Once there are tadpoles in the aquarium, they will change gradually into young frogs. In nature tadpoles are scavengers, but in the aquarium they will eat goldfish food.

When the tadpoles are partially developed, the teacher should have the life cycle of frogs. Some things to be discussed are:

1. Where do frogs spend their nights?
2. How does the life cycle of frogs compare to that of beetles?
3. What part of the beetle life cycle does the tadpole compare to?

At this point the pupils should draw the beetle life cycle and the frog life cycle and relate the steps of the two cycles.



The pupils should see from this that the pupa stage is absent from the frog's life cycle. They should also see again as in the beetle life cycle that this does not take place in distinct steps but rather in a continuous process.

One word of caution to the teacher is that if you get the eggs from a bullfrog (*Rana catesbeiana*) they will take two years to develop and are therefore not suitable for this activity. The chances of getting bullfrog eggs is slight, however.

ACTIVITY 3. Hatching Chickens

Introduction

This activity must be carried on over a period of several weeks. In keeping with this, the teacher might wish to start this activity concurrently with another one.

Materials

chicken eggs
small jars (baby food jars with lids)
isopropyl alcohol
incubator

Procedure

There are two ways to start this activity; you may use an incubator and start your eggs right at the beginning, or you may purchase incubated eggs from a hatchery.

Most local hatcheries will let you have eggs that have been incubated for a given number of days right up to eggs in their 21st day and ready to hatch. If you bring hatchery eggs right back to the classroom wrapped in wool to insulate them, the eggs may be used as if they had come from a classroom incubator.

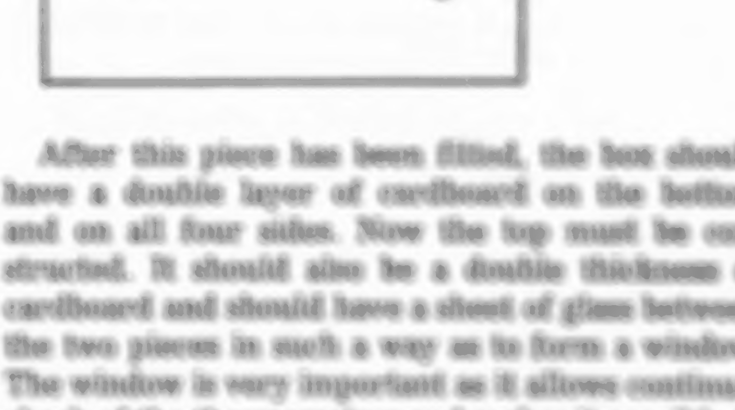
But, if you choose to incubate your own eggs, there are several points to keep in mind:

1. The temperature must stay at 100° F.
2. The humidity must stay high.
3. The eggs must be turned every day.
4. The eggs must be fertile to start.

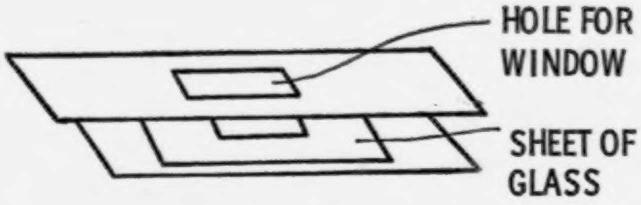
You may buy a small incubator from most any scientific supply house or have your pupils build their own. If you decide on the latter, you will probably end up with a larger incubator.

Start your incubator with a cardboard box which measures about 24" x 12" x 12" and cut the top off.

Set a piece of cardboard on the bottom of the box so that it gives a double layer. Cut a strip of cardboard about one inch shorter than the height of the box and long enough to go all the way around the four sides on the inside.

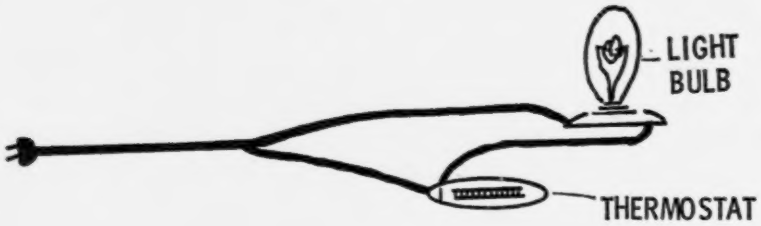


After this piece has been fitted, the box should have a double layer of cardboard on the bottom and on all four sides. Now the top must be constructed. It should also be a double thickness of cardboard and should have a sheet of glass between the two pieces in such a way as to form a window. The window is very important as it allows continual check of the thermometers and makes it possible to watch the hatching of the eggs without drying or chilling the chicks.



Tape these two sheets of cardboard together with masking tape, and the sheet of glass will stay securely in place. It is important that the top be cut so that it fits as tightly as possible into the box and about one inch from the top.

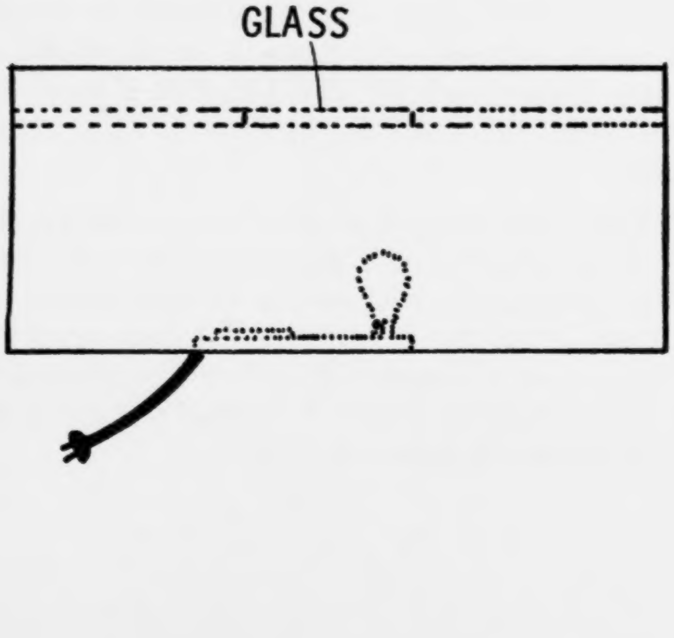
A 25-watt light bulb will provide all the heat necessary, but this bulb must be hooked in series with a thermostat.



The thermostat should be fastened to a board and set in the bottom of the box. The local heating and air conditioning firm often will have old thermostats which are sold cheaply or given away.

Once the pupils have made this construction, they are ready to start hatching eggs. The eggs must be fertile, so it is best to purchase the eggs from a hatchery or a farmer that can furnish fertile eggs. Eggs purchased in a grocery store are seldom fertile.

Once the incubator has been checked to make sure that it is maintaining a constant temperature of 100° F., the pupils can put in the eggs. At this time the pupils should put a pan of water with a sponge into the incubator to maintain a high humidity.



The eggs should be turned over every day for two weeks. If the pupils pencil an X on one side of each egg, they can tell if all eggs have been turned.

Have the pupils open an egg every four days, place the embryo in a small jar of isopropyl alcohol, and label it. At the end of 21 days when the chicks have hatched, the class will have a series of embryos which show the development of the embryo chick in the shell

A class discussion at this point will review what has been learned about hatching eggs and how this fits into the life cycle of chickens. Some points that should be covered are:

1. Does this development take place in jumps or is it continuous?
2. Does a chicken have a larvae form like the beetle or frog?
3. How do eggs get turned in nature?
4. How does 100° F compare with the human temperature?

CONCEPT: One of the important cycles found in nature is the gas cycle that takes place between oxygen and carbon dioxide.

ACTIVITY 1. Gas in the Rocks

Introduction

Limestone is very abundant in Iowa and therefore easy to obtain. Limestone is made of calcium and carbon dioxide, the same materials of which snail shells and clam shells are composed.

Materials

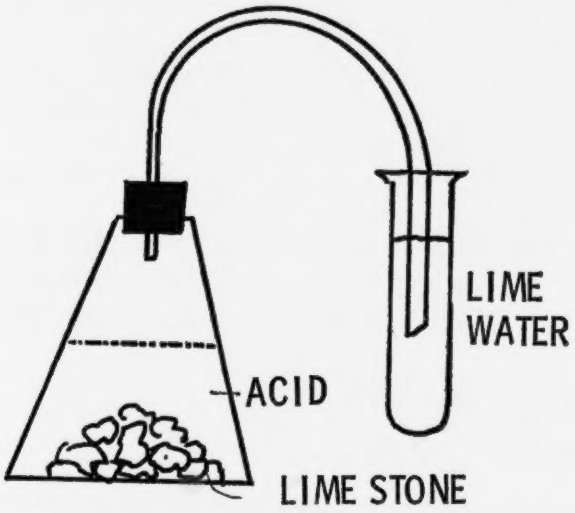
limestone
dilute hydrochloric acid or vinegar
clam shells

Procedure

Divide the class into four or five groups and provide each group with a sample of limestone, a dropper bottle of dilute acid, either vinegar or hydrochloric acid; and a clam shell. Dilute hydrochloric acid is not dangerous if used with care. If any is spilled it can be neutralized with soda bicarbonate.

Once the groups have been provided with the necessary materials, they should be instructed to put a drop of acid on the limestone to see what happens. Limestone is made of calcium and carbon dioxide. The teacher should describe calcium (a white powder) and carbon dioxide (a colorless gas). The pupils should be asked what has been released from the limestone. Because it bubbles and has no color, the pupils should infer that CO_2 is being liberated.

If they make this inference, ask if it can be tested. The teacher should tell the class about limewater and how it is a test for CO_2. To test the gas that is given off when acid is dropped on limestone, it is necessary to cause the liberated gas to bubble through the limewater. This can be done by placing limestone in a flask, pouring in dilute acid (hydrochloric), and covering the flask with a one-hole stopper into which a glass tube has been placed. This tube should be bent in such a way that the end will fit into a test tube of limewater.



The limewater, which is clear, will turn cloudy if CO_2 is bubbled through it in this manner.

A class discussion should follow in which the properties of CO_2 are discussed. Some points that should be covered are:

1. CO_2 is produced whenever anything burns.
2. CO_2 is a compound formed by combining carbon and oxygen.
3. The CO_2 locked in limestone is out of the gas cycle until it is unlocked.
4. Green plants must have CO_2 to produce sugar.

Have the groups take a sea shell, or a piece of sea shell, and have them repeat the process of testing with a dilute acid. If the sea shell bubbles, the groups should formulate a theory to explain why.

ACTIVITY 2. CO_2 from Sugar

Introduction

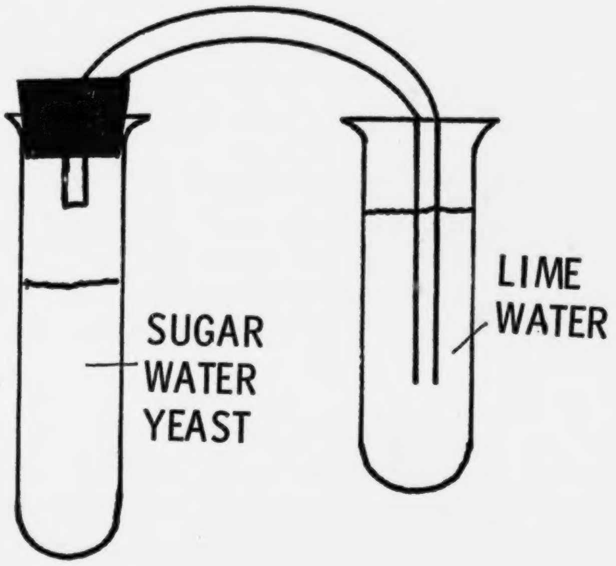
CO_2 is locked out of the oxygen-carbon dioxide cycle in many ways. Limestone is one way. This activity deals with CO_2 which is locked out of the cycle in sugar.

Material

test tubes
one-hole stoppers
glass tubing
yeast
sugar
limewater

Procedure

Divide the class into four or five groups and provide each group with two test tubes, a one-hole stopper, tubing, sugar, yeast, and limewater. Instruct the pupils to dissolve about one teaspoon of sugar in a test tube and then add about a fourth of a cake of yeast to the sugar water. The test tube should then be stoppered with a glass tube stuck into the stopper and run into a test tube of limewater.



The apparatus should then be set in a warm part of the room and observed for the rest of the day. After a while the sugar water should start to bubble as a gas is released; this gas will be identified as the limewater clouds up. It is CO_2 that is being released, and this presents a problem for the pupils to solve.

At this point make a reading assignment on the subject of fermentation. Encyclopedias will probably be the pupil's best source of information on this topic. After the assignment has been completed, the process of fermentation should be discussed. The class should be aware of several key points by the end of the discussion such as:

1. Yeast strips CO_2 of the sugar molecule.
2. Once the CO_2 has been taken off, the sugar molecule is turned into a molecule of alcohol.
3. By this process CO_2 is returned to the gas cycle.

ACTIVITY 3. Oxygen in Our Atmosphere

Introduction

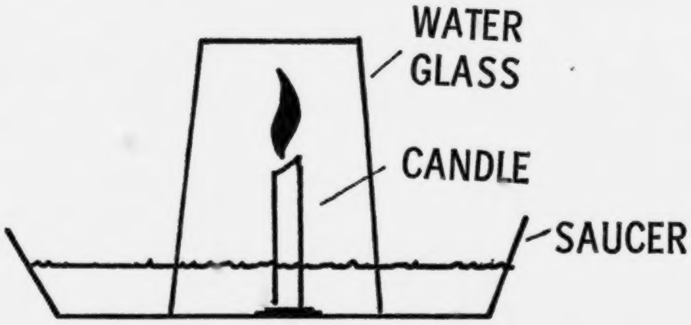
Oxygen is one of the most important gases in our atmosphere from a human point of view. This activity will give the pupil an insight into the amount of oxygen in the air.

Materials

water glasses
saucers
birthday candles

Procedure

Divide the class into as many groups as you have material for and give each group a drinking glass, saucer, and candle. Instruct them to melt a little wax on the saucer and fasten the candle in the center of the saucer. Then fill the saucer with water and light the candle.



When the candle is burning well, place the inverted water glass over it and observe the results.

When the class has performed this activity several times, the teacher should discuss the results.

Some points to be covered are:

1. What happens to the air that was replaced by water?
2. The air is about 20 per cent or one-fifth oxygen. How does this compare with the amount of air replaced by water in the glass?
3. Could an animal live in the air that is left after the candle has gone out?
4. What part of the air is left?

ACTIVITY 4. Effect of CO_2 on Growing Plants

Introduction

All living organisms depend on gas from the gas cycle in the atmosphere, either CO_2 or O_2.

Materials

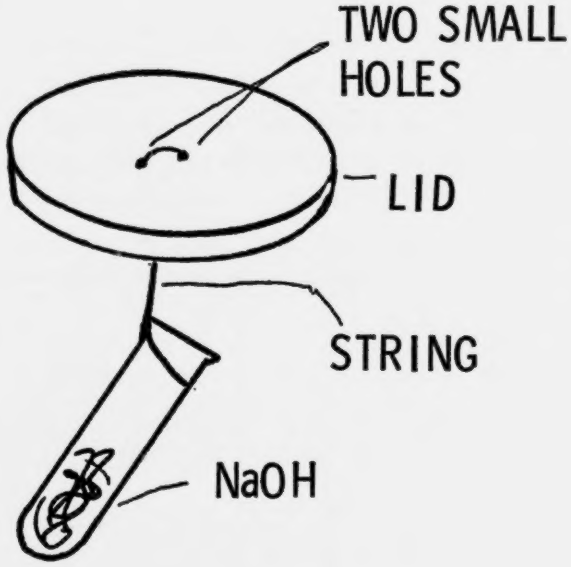
wide mouth gallon pickle jars with lids
bean seeds
sodium hydroxide (NaOH)
steel wool
test tubes
potting soil

Procedure

Conduct an experiment in which the class eliminates certain parts of the gas cycle. There will be three experimental groups and one control group. In one group the oxygen will be controlled and in another the carbon dioxide will be controlled. Another group will provide extra carbon dioxide for its plants. The last group will provide a *control.* It will allow every type of condition to affect its plants that will affect the plants of the other groups except that it will not try to control any of the conditions.

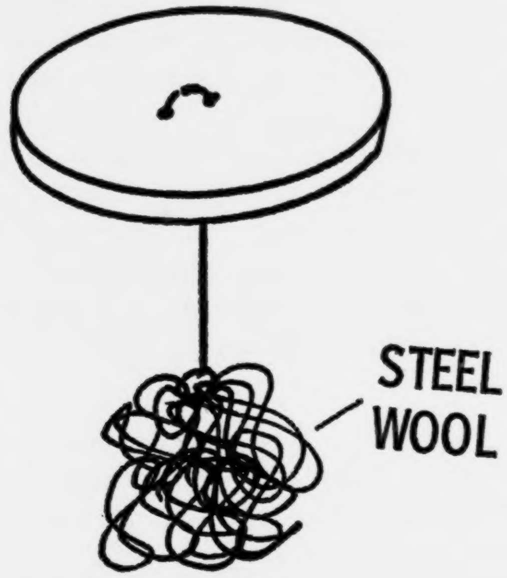
Give each group a large-mouth pickle jar, potting soil, and seeds. Have the groups plant the seeds in the potting soil. Have each group water its seeds and place the lids on the jars. After several days, the beans will have sprouted to a height of about two inches.

Have the first group take the lid off its jar and punch two small holes in it. Through these holes have the pupils tie a string to which is attached a small test tube half full of sodium hydroxide (NaOH).



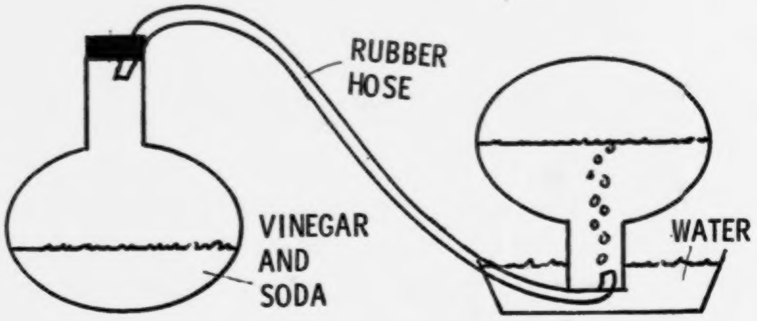
Sodium hydroxide is *very caustic* so it must be handled with *extreme care*. Have the pupils place the lid on the jar and melt several drops of candle wax over the holes to seal out the air. This will eliminate the CO_2 from this jar as the sodium hydroxide will absorb it. In this way it will eliminate CO_2 from the gas cycle. This jar should now be labeled and set aside.

The second group should follow the same procedure. A string should be fastened through the holes with a small bundle of steel wool attached to the other end. The two holes in the lid should be sealed with candle wax also.



This steel wool will oxidize and take the oxygen out of the gas cycle within the jar. Rust is oxygen and iron, and the steel wool will rust and lock up the oxygen. This jar should now be labeled and set aside.

The third group should collect CO_2 gas over water by the following method: Mix 200 ml. of vinegar with two or three teaspoons of soda bicarbonate in a 1,000 ml. flask and insert a one-hole stopper with rubber tube attached into the flask. Let the gas that is given off bubble up into an inverted flask full of water until the gas replaces all of the water.



The flask of gas collected should be poured into the group's pickle jar, where the bean shoots are growing. CO_2 can be poured because it is heavier than air. (This can be proved by pouring CO_2 into a jar in which there is a burning candle. As the heavy CO_2 forces out the air, the candle will go out.)

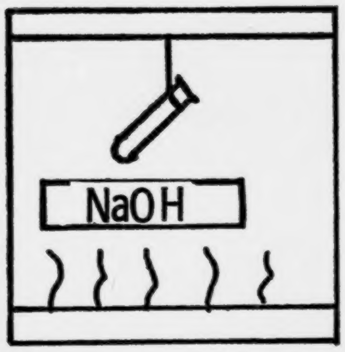
This third group, unlike the others, will have to repeat this operation every day for the length of the experiment. This jar should now be labeled and set aside.

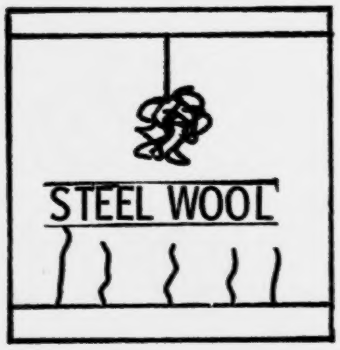
The fourth group will have only to label its jar and set it aside because this is the control jar and nothing will be done to it.

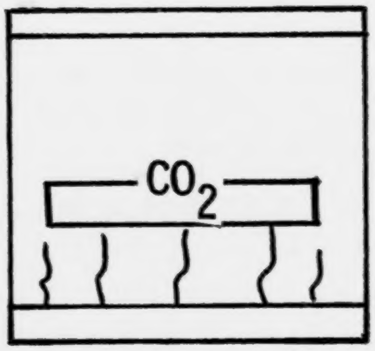
The four jars should now be sitting together in a place where they can be observed daily.

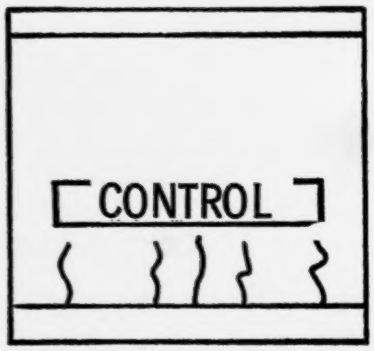
They should be observed and the observations recorded every day. At the end of two or three weeks the results should be discussed in class, and the class should draw conclusions which explain the results of the experiment.

This is just one run of the experiment. If a scientist were conducting it in a laboratory, he would repeat it many times. The one time that the class runs the experiment would be the most likely time for discrepancy between expected outcome and actual outcome, if any.









EVALUATION

This unit is to be evaluated in such a way as to determine the understanding of individual pupils. Does the pupil see the life cycle of an animal as chopped up into bits and pieces, or does he recognize it as a smooth complete circle? Does he see this life cycle as applying to just the animals studied or does he transfer the knowledge that he has gained so that he can apply it to any animal or group of animals? Does the gas cycle apply only to oxygen and carbon dioxide or can he see broader implications?

To determine these and other questions, the teacher should create new situations where the pupil can apply the concepts and knowledge gained in this unit. Factual tests should not be used as evaluation tools for this unit.

List of Materials Needed for 4th Grade

250 ml. pyrex beaker
500 ml. beakers
500 ml. erlenmeyer flasks
one hole stopper to fit flasks
glass tubing
rubber tubing to fit glass tubing
meter stick
1,000 ml. graduated cylinders
pint measure
balance
set of gm. weights
thermometers
  Fahrenheit (0-215 degrees)
  Centigrade (-20-110 degrees)
magnetic compass
light meter
telescope
microscope
microscope slides (blank)
aquarium 2-10 gallons
tank heater (if tropical fish to be kept)
thermometer for fish tank
1,000 ml. pyrex beaker
100 ml. beaker
bunsen burner or alcohol lamp
ring clamp
ring stand
wire gauze
test tube rack
large test tubes with rubber stoppers
capillary tubing 3 or 4 sizes
triangular file
transparent grid
100 ml. graduated cylinder
large ring clamp
3" ring clamp
hygrometer
rain gauge
sling psychrometer
400 ml. beakers
battery jar
6-volt lantern cell
6-volt bulb and socket
test tube clamp
copper wire
aluminum wire
iron wire
electrical wire
copper
lead
iron
zinc
aluminum
mercury
sulfur
iodine solid
carbon (graphite in solid form)
gases
  oxygen
  nitrogen
alcohol
ammonium chloride (NH_4Cl)
cigar boxes
tape
cylindrical piece of wood
balloons
rocks
marking pencil
blocks (assorted sizes, very small to obvious size)
paper
ruler
quart glass jar
pail
paper clips
gravel
plants
fish
snails
nets
gold fish
seeds
  corn
  beans
  radish
candle
square pans 10" x 10"
potting soil
flower pots
gallon jug—wide mouth
sheets of window glass 6" x 6"
salt
distilled water
cooking oil
sand
sugar
plastic dish pan
2 glass plates 10" x 12"
masking tape
razor blades
embroidery hoop
cotton balls
2 pyrex pie pans

- small mirror
- black soil
- food coloring
- 3" x 5" cards
- string
- plastic bags (large "Baggies")
- knives
- saran wrap
- rubber bands
- construction paper
- baking soda
- vinegar
- wide mouth jars with lids
- wood splints
- modeling clay
- proof paper or photo copy paper
- buttons
- knitting needles

List of Materials Needed for 5th Grade

- meter sticks
- metric ruler
- spectroscope
- bunsen burner or alcohol lamp
- tongs
- magnesium ribbon
- iron wire
- copper wire
- 100 ml. pyrex beaker
- 250 ml. beaker
- pyrex test tubes
- centigrade thermometers
- utility clamps
- 500 ml. florence flasks
- corks to fit flasks
- medicine droppers
- 100 ml. graduated cylinders
- ring stands
- 500 ml. pyrex beakers
- wood splints
- rubber tubing
- ring clamps
- large round glass battery jar
- 1,000 ml. beaker
- zinc strips
- magnifying glass
- collecting boxes
- weights
- spring scales
- model of a dinosarus
- fossil specimen
- bar magnets
- iron filings
- small compasses
- #28 gauge cloth insulated wire
- batteries 1 1/2 dry cell
- large test tube
- telephone batteries
- horseshoe magnets
- bell wire
- magnetic compass
- equal arm balance
- spring balance
- copper sulfate
- strantzim chloride
- calcium carbonate
- paradichlorobenzene (M.P. about 51%)
- glycerine
- isopropyl alcohol 70%
- blue litmus paper
- pink litmus paper
- mercuric oxide (mercury II oxide HgO)
- lead acetate ($Pb(CH_3COO)_2 \cdot 3H_2O$)
- plaster of paris
- 1 spray can of clear acrylic or clear lacquer
- 8" x 11 1/2" sheets of white paper
- rollers
- blocks
- small toy trucks
- 12" ruler
- 6" protractor
- thumbtacks
- thread
- weight (nut, key, or sinker)
- cardboard 8 1/2" x 11"
- pencil
- small rubber ball 3" - 5" in diameter
- strong string
- angle elevation device
- camera
- tripod
- world globe
- flashlight
- paper
- salt
- 4" x 6" unlined white cards
- stainless steel teaspoon
- colored pencils

paper clips
gum drops
toothpicks
cigar box
masking tape
1 fresh egg
powdered sugar
rope
small buckets (about 2 qt.)
wheels
baking soda
vinegar
paraffin wax (M.P. about 38° C)
distilled water
household ammonia
4 tablespoons
orange
lemon
grapefruit
borax
washing soda
tea
red cabbage
steel wool
3/8" x 6" wooden dowel
assortment of pulleys
sand
1/2" metal chisel
small hammer
talcum powder
clay
clam shells
note book
paints
construction paper
paste
miscellaneous art supplies
boards 3—4' long 6" wide
The Handbook of Fossils (A guide to prehistoric life published by Golden Press, New York, $1.00)

List of Materials Needed for 6th Grade

250 ml. beakers
wire gauze
glass tubing
one-hole stopper to fit glass tubing
large test tube
meter sticks
spring scale (calibrated in grams)
meter stick clamps
100 gm. weights
250 ml. erlenmeyer flasks and stoppers
400 ml. beakers
50 ml. pyrex erlenmeyer flasks
thermometers—Centigrade
500 ml. beakers pyrex
bunsen burners or alcohol burners
ring stand
ring clamp
1,000 ml. beaker
petri dishes
large ring clamp
utility clamp
test tubes
test tube racks
200 ml. bottles and stoppers
medicine droppers
500 ml. florence flasks
aquarium
test tube holder
hand lens or magnifying lens
teasing needles
plastic tubing
incubator
iodine crystals
isopropyl alcohol
lead nitrate ($Pb(NO_3)_2$)
copper sulfate ($CuSO_4 . 6 H_2 0$)
potassium thiocyanate ($KSCN$)
ferric nitrate ($Fe(NO_3)_3 \bullet 9H_2O$)
potassium nitrate (KNO_3)
dibasic sodium hydrogenphosphate (Na_2HPO_4)
calcium carbonate ($CaCO_3$)
sodium hydroxide ($NaOH$)
phenolphthalein
methyl orange
potassium alum ($KAL(SO_4) . 5 H_2 0$)
litmus paper
sodium thiosulfate (photographer's hypo)
limestone
dilute hydrochloric acid
limewater
galena
magnetite
olivine
cinnabar
gypsum
stibnite

- graphite
- copper
- calcite
- halite
- feldspar
- orthoclase or plagioclase feldspar
- quartz
- hornblende
- mica
- muscovite or biotite
- pyrite
- rock specimens
  - igneous
    - granite
    - gabbro
    - felsite
    - basalt
    - obsidian
  - sedimentary
    - conglomerate
    - sandstone
    - shale
    - limestone
    - coal
  - metamorphic
    - gneiss
    - mica
    - schist
    - slate
    - marble
    - quartzite
- globe model of earth
- scissors — tin snips or other cutting tool
- tennis balls — hollow rubber balls
- ruler
- string
- cooking oil
- salt
- sugar
- distilled water
- soil
- dishpan
- sand — must be clean (SiO_2)
- red cabbage
- vinegar
- ammonia
- cotton
- quart jar — wide mouth
- bean seed
- potatoes
- bran
- potting soil
- meal worms
- toad or frog eggs
- shallow glass dishes
- chicken eggs — fertile
- small jars — baby food jars with lids
- clam shells
- yeast
- water glasses
- saucers
- birthday candles
- wide mouth gallon jars with lids
- pebbles
- gravel
- mercator map (wall map) of the world
- white butcher paper or wrapping paper
- marking pencils
- road map (Iowa road map)
- topographic maps (local area)
- colored pencils
- paper
- pencil
- grease pencil
- model of solar system
- picture of galaxies
- weight (nail or bolt)
- penny
- paper clips
- glass plate
- unglazed porcelain tile
- stick pins
- colored stars
- knife
- nail file
- piece of glass
- 2 plastic refrigerator containers one with a lid
- masking tape
- steel wool
- closed container
- drinking straws
- clay